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UNIVERSITY OF ALBERTA

A STUDY OF THE PERFORMANCE OF HYDROCYCLONES FOR DESILTING DRILLING FLUIDS

BY

F. DEAN TERRIEN ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF
Master of Science
IN
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DEPARTMENT OF
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ABSTRACT

Desilters are small diameter hydrocyclones that are used in the petroleum industry to separate fine drill solids from drilling fluids. A desilter is functioning properly if it is maximizing solids recovery while minimizing liquid recovery to the underflow. A series of experiments was done to study the operational characteristics of the hydrocyclone desilter. Both water-only and bentonite drilling fluids were evaluated in the experiments using a hydrocyclone pilot plant. A new hydrocyclone underflow spigot, known as the JD spigot, was developed at Mount Newman Mining to help improve their dewatering capabilities. The JD spigot reduces water recovery while increasing the percent solids concentration to the underflow. The JD spigot was included in the hydrocyclone testing of this study to determine if there was an application for this device in the petroleum drilling industry. Moreover, there has been no work reported on using JD spigots with small diameter hydrocyclones.

A secondary objective of this investigation was to evaluate two hydrocyclone mathematical models (Plitt and Sharma models). Performance parameters from the experiments were compared to those predicted from the models.

Results indicate that, under certain operating conditions, the JD spigot does have an application in solids control systems on rotary drilling rigs. The JD spigot reduces the water recovery to the underflow, but the solids recovery is somewhat compromised. However, conventional

spigots have a tendency to plug up during drilling operations, whereas the JD spigot displays no plugging tendencies. Size analysis of the underflow and overflow samples illustrates that the cut size of a desilter operation, when using JD spigots, increases slightly. However, the partition curves show that the sharpness of separation is not compromised when using JD spigots.

The Plitt correlation is somewhat successful at predicting flow split and cut size values for both water-only and bentonite drilling fluids. However, the Plitt pressure drop and sharpness of separation correlations require some calibration to improve their predictive accuracy. Finally, the Sharma model is unsuccessful at predicting any of the performance parameters in its present form.

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NOMENCLATURE

A_i = cross sectional area of hydrocyclone feed inlet.

B = base diameter of the JD spigot.

C_d = drag coefficient.

D_c = inside diameter of the cylindrical portion of a conventional hydrocyclone.

D_i = inside diameter of feed inlet = $\sqrt{\frac{4\ (A_i)}{\pi}}$ for non-circular inlets.

D_o = inside diameter of the overflow opening or (vortex finder) of a hydrocyclone.

D_u = inside diameter of the underflow opening/apex of a hydrocyclone.

d = particle size diameter.

d_i = characteristic size of a particle size class.

d_{25c} = particle size (corrected for liquid) that has a 25% chance of going into the underflow.

d_{75c} = particle size (corrected for liquid) that has a 75% chance of going into the underflow.

d_{50} = cut size of a partition/classification curve: the particle size that has a equiprobable chance of reporting into either the overflow/underflow streams.

d_{50c} = corrected cut size of a partition/classification curve: same as the d_{50} except it has been corrected for liquid reporting into the underflow.

E_p = probable error of a partition curve.

F_c = centrifugal force.

F_d = drag force.

F_1 = calibration parameter for Plitt hydrocyclone model, default value = 1.0.

F_2 = calibration parameter for Plitt hydrocyclone model, default value = 1.0.

F_3 = calibration parameter for Plitt hydrocyclone model, default value = 1.0.

F_4 = calibration parameter for Plitt hydrocyclone model, default value = 1.0.

h = free vortex height of a hydrocyclone.

H = pressure drop across a hydrocyclone in head of feed slurry.

I = the imperfection of a partition curve.

L = wedge length of JD spigot.

L_v = length of vortex finder.

m = sharpness of separation.

P = pressure drop accross a hydrocyclone or inlet pressure.

Q or Q_i = volumetric flow rate of inlet feed slurry.

r = radius of separating particle and orbit.

Rc = radius of a hydrocylone.

Re = Reynolds number $\frac{V_i\ D_i\ \rho_f}{\mu}$.

r_t = radius of cone where v_t is measured.

Rf or R_f = volumetric feed liquid reporting at underflow.

R_v = volumetric feed slurry reporting at underflow.

Rs or R_s = volumetric feed solids reporting at underflow.

S = flow split: ratio of underflow and overflow volumetric flow rate.

$\%SIL$ = recovered drill solids at the underflow.

$\%SIL_c$ = recovered drill solids at the underflow corrected for water and bentonite.

V_i = inlet velocity of the feed.

V_o = volumetric flow rate at the overflow.

v_r = radial velocity.

v_t = tangential velocity.

V_u = volumetric flow rate at the underflow.

v_v = vertical velocity.

y = mass fraction of solids reporting to the underflow.

y_i = mass fraction of solids reporting to the underflow. corrected for underflow liquid.

α = parameter representing sharpness of separation in Equation (3-20).

α_i = parameter dependent on design and fluid properties.

η = effective viscosity $\dfrac{\mu\ D_c}{(\rho_s - \rho_f)\ Q_i}$.

θ = cone angle of hydrocyclone.

μ = apparent and absolute viscosity of liquid in the feed slurry.

ρ_f = fluid density.

ρ_s = solids density.

ϕ_s = mass fraction of solids in the feed.

ϕ = volumetric fraction of solids in the feed.

CHAPTER I

INTRODUCTION

The petroleum drilling industry began in North America in the mid 1800's. It was during this time period that crude oil (liquid hydrocarbon) was identified as a source of fuel, and that it could be used as a lubricant for mechanical equipment. Since then, oil companies have continuously explored for crude oil, as well as natural gas, to supply society with plastics, engine fuels, home heating fuels, chemicals and solvents.

In order to retrieve hydrocarbons from beneath the surface of the earth, a conduit must be established as a means of getting the hydrocarbons to the surface. This requires a surface structure capable of drilling anywhere from 500 to 6000 m into the earth's crust.

The earliest wells were drilled using the cable tool method. This method involved raising and dropping a steel bit into the ground to advance the depth of the hole. Once the hole had accumulated an abundance of drill cuttings, they were removed with a bailer that was run into the hole. This method of drilling was slow and tedious, and could be quite unsafe if fluids and/or gases from penetrated zones flowed into the wellbore. The fluids were basically uncontrolled because there was no material on top (that would apply hydrostatic pressure) to hold down the pressure from below. However, many of the original oil wells drilled in the United States and Canada employed the cable tool method of drilling. Unfortunately, there were many blowouts (uncontrolled flow of formation fluids from a well) resulting from the use of cable tool drilling.

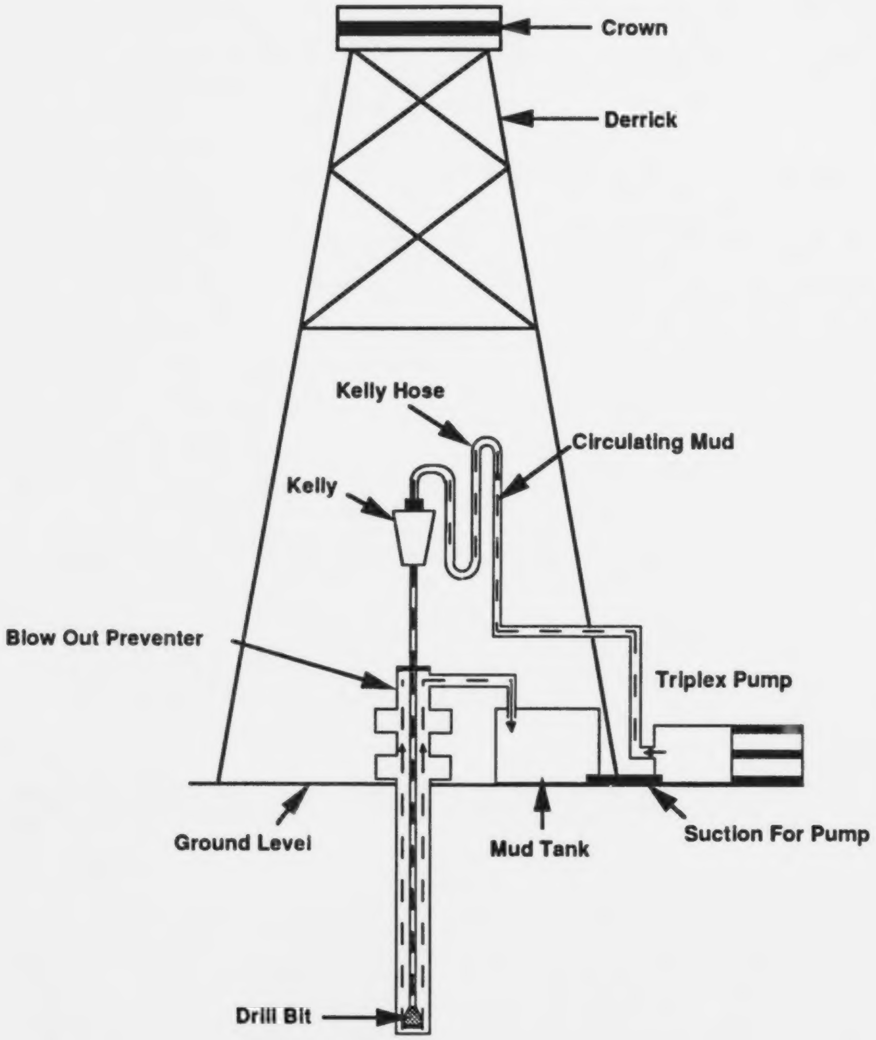
In the early 1860's, a new method called rotary drilling was introduced to the petroleum industry. This method was much better at helping control subsurface formation pressures because a circulating fluid was always in the hole administering a force downward onto the producing formations. The rotary method of drilling involved the use of a rotating bit to advance the drilling action.

In a typical rotary drilling operation (Figure 1-1) drilling fluid is pumped down the centre of the drill pipe and through small jets that are on the bottom of the drill bit. The drill cuttings are then carried up the annulus by the circulating fluid and out the hole where they are transported through the solids separation equipment.

Rotary drilling is now the only method of drilling used by oil companies to penetrate hydrocarbon formations in the earth's crust. Drill cuttings are removed by circulating the drilling fluid out of the hole. Once on the surface, separation equipment removes the accumulated solids; the remaining fluid is then recycled back down the hole.

It is now recognized in the oil and gas industry that drill solids have a significant influence on the technical and

Figure 1-1: A Rotary Drilling Rig


Crown
Derrick
Kelly Hose
Circulating Mud
Kelly
Blow Out Preventer
Triplex Pump
Ground Level
Mud Tank
Suction For Pump
Drill Bit

economic success of all drilling operations. The importance of solids control in any drilling operation is evident when increased well costs and drilling problems can be correlated directly with problems with the drilling fluid. The problem usually is the buildup of drill solids in the drilling mud system.

Today, almost 100% of all the oil and gas wells drilled in the world employ the rotary drilling method. In Canada there is usually an average of 6000 wells drilled every year at an estimated total cost of $3 billion. Moreover, in 1994 the well total could reach 10000 in Canada, with an overwhelming majority of the wells being drilled in the Western Canadian sedimentary basin.

The average depth of most wells is usually between 1500 m and 2000 m. Wells are generally drilled with water for the first 1500 m of depth; after 1500 m, additives are placed in the mud system to help control the mud viscosity and to slow the fluid loss to the drilled formations. Typically, the penetration rate to 1500 m is faster than below 1500 m because no additions have to be made to the water. Moreover, the jetting action of the bit is maximized because of the absence of any weighting or viscosifying material. As mentioned before, solids control equipment accompanies all rotary drilling rigs. Improvements to the solids control equipment help increase the drilling penetration rate because the more solids taken out on the surface the fewer that return down the hole where they compromise the jetting action through the nozzles of the bit. An improvement in the removal of solids at surface increases the drilling penetration rate of a rotary drill bit, and, at the same time, reduces the costs associated with drilling operations. Today, as most drilling operations become increasingly more complicated, drilling engineers should understand the causes of drilling efficiency and how it is affected by the presence of drill solids in the mud system. By paying attention to this, engineers can improve on drilling optimization as well as the cost of the operation.

The main thrust of this investigation was to study one particular part of the solids control system used on rotary drilling rigs, specifically, the desilter hydrocyclone, an important component of most solids control systems. The main goal of this study was to find ways to improve the solids recovery in a mud system.

CHAPTER II

HYDROCYCLONE USE IN THE DRILLING INDUSTRY

2.1 Introduction

Hydrocyclones are used extensively as solids separation equipment in the mineral processing and oilfield drilling industries. The primary use of hydrocyclones in the petroleum drilling industry is that of a "desilter" or "desander". Desilters and desanders remove silt and sand sized particles, respectively, from fluid streams. These particles constitute drill solids (cuttings or other undesirable solids) in drilling fluids during rotary drilling operations. The concentration of drill cuttings usually varies between 1% and 6% by volume in the mud system when it enters the solids control equipment (Ormsby 1982).

Hydrocyclones used in the drilling industry act as classifiers or thickeners. A classifier describes the separation of fine and coarse solids in a drilling fluid circulation system. A thickener describes an operation where all drill solids are rejected to waste, leaving the liquid phase in the mud system. Thickening is also known as dewatering, where the goal is to remove all solids from a specific slurry, which results in clarification of the liquid.

The hydrocyclone was first used in the drilling industry in 1952, as described by Stone (1961). Stone reported how using hydrocyclones for solids removal from drilling fluids improved the penetration rate during drilling operations. Later, Stone (1964) revealed how using desilters improved Gulf's drilling efficiency and reduced drilling fluid costs. At that time operating companies realized the potential importance of including hydrocyclones in solids control systems. Prior to the use of hydrocyclones in drilling, solids removal from drilling fluids was accomplished through the use of shale shakers and settling pits (Nelson 1971). The drilling industry was not yet concerned about the buildup of drill solids in drilling muds. The solids buildup within a drilling mud results in an increase in specific gravity and viscosity of the fluid, either or both of which may be undesirable. Initially, thinners and water were added to control increases in specific gravity and viscosity. However, some muds were turning into cement in deep, high-temperature wells as a result of these additions. Without question, the most serious contaminant in drilling fluids (affecting drilling performance) are the drill solids. Table 2-1 below lists four main methods commonly used to control solids buildup in drilling fluids.

Table 2-1

Methods of Controlling Drill Solids

(After Marshall and Brandt 1978)

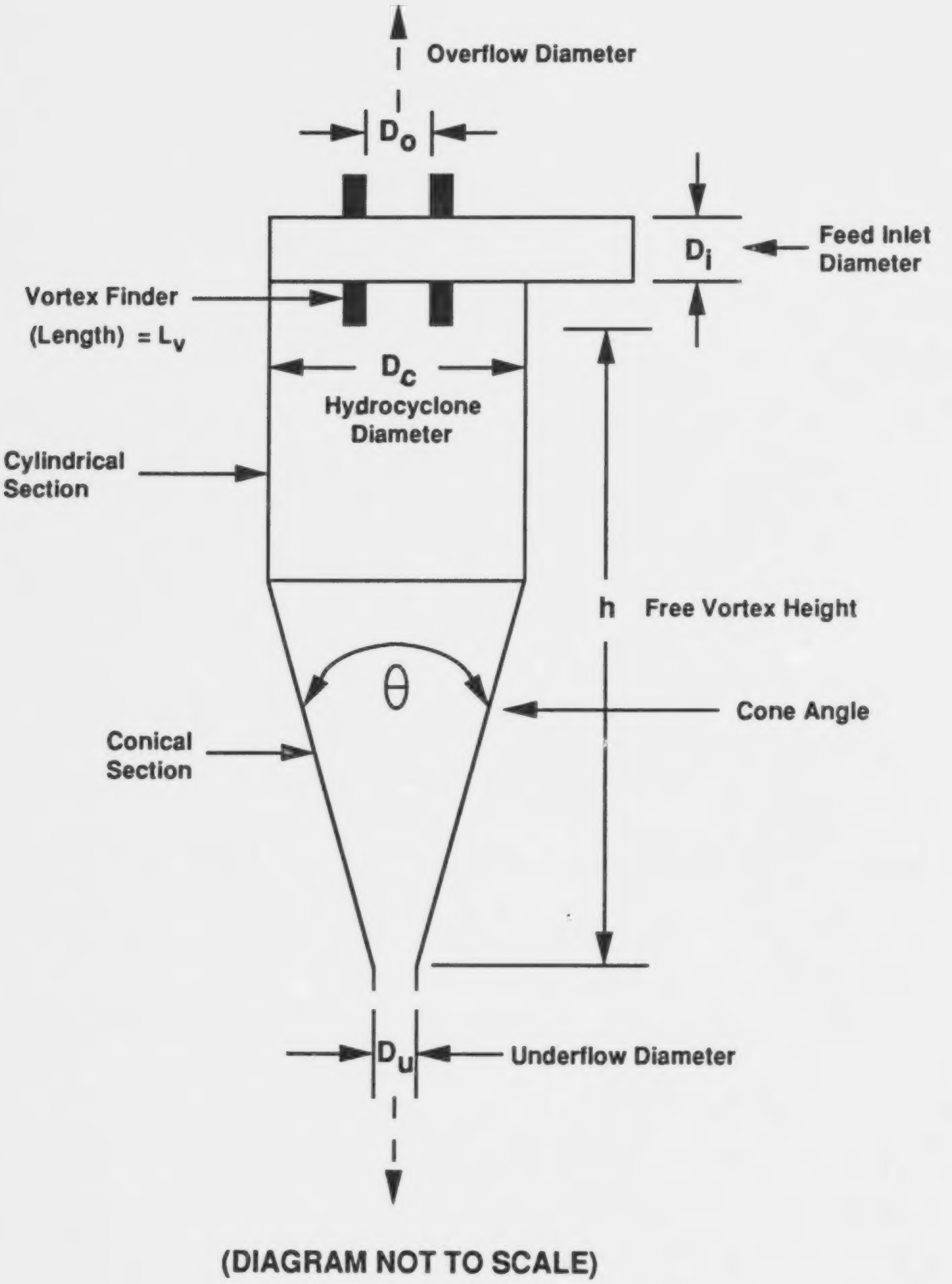
1. Mechanical Treatment
2. Dilution of the Whole Mud System (Adding Water)
3. Jetting of Whole Mud System (Replacing the Whole System)
4. Chemical Treatment (Using Flocculants)

2.2 Design Variables of Hydrocyclones

The diameter of the hydrocyclone (D_c) specifies the relative size of the hydrocyclone (see Figure 2-1). Depending on the specific size needed for an operation, various inlet and outlet sizes are available for most hydrocyclones. Centrifugal forces are the mechanism of separation in hydrocyclones. These forces are dependent upon specific gravity differences between liquids and solids in the feed stream. Figure 2-1 displays a basic conventional hydrocyclone which utilizes high centrifugal forces to separate specific solid and liquid phases in a feed stream. This group of hydrocyclones usually has a smaller cone angle (see Figure 2-1) and the length (h) is large (that is, large free vortex height), compared to the diameter. The length of the body can be up to seven times as long as the hydrocyclone diameter; however, this ratio is usually three to four.

A hydrocyclone is a separation device with one inlet stream and two output streams. The inlet stream is the feed, the bottom output stream is the underflow and the top output stream is the overflow. Discharge orifices, (D_u) and (D_o), (diameter of the underflow and overflow, respectively) are typically very small compared to the diameter of the hydrocyclone. Orifice sizes can be varied, thereby significantly increasing or decreasing volumes of solids and liquids reporting to either the overflow or underflow. The underflow and overflow are also known as the apex and vortex

Figure 2-1: A Conventional Hydrocyclone With Dimensional Variables


Overflow Diameter
D_o
D_i
Feed Inlet Diameter
Vortex Finder
(Length) = L_v
D_c
Hydrocyclone Diameter
Cylindrical Section
h
Free Vortex Height
θ
Cone Angle
Conical Section
D_u
Underflow Diameter

(DIAGRAM NOT TO SCALE)

finder, respectively.

Most conventional hydrocyclones have interchangeable parts allowing orifice sizes to be easily changed during an operation. Underflow sizes are changed by adding spigots (spigots are inserts of varying sizes that can be installed in the apex of a hydrocyclone to change the underflow diameter). The overflow diameter is modified by changing the cylindrical head of the hydrocyclone; this usually changes the inlet diameter also. For the inlet feed diameter, D_i, different shapes, usually round or rectangular can be used.

2.3 Benefits of Using Hydrocyclones

Operating and drilling companies are faced with both continuously increasing drilling costs and the requirement to drill to greater depths. As a result, at these depths, companies are finding it an economic advantage to become more knowledgable of technologies related to efficient solids control. Some of the advantages of using hydrocyclones to control specific drilling fluid properties include:

1) **An Increase of drilling penetration rate:** silt-free drilling fluid returning down the drill pipe allows for an optimized jetting action at the drill bit, thereby improving the drilling rate and removal of new drill cuttings from the wellbore.

2) **Reduced equipment maintenance:** wear on equipment is reduced

when using low solids (particularly silt) drilling fluids. Silt is abrasive and the longevity of pump parts and other equipment increases if the quantity of silt is reduced.

3) Increased bit life: bits used with desilted drilling fluid operate more efficiently and are able to cut more effectively into wellbore formations, thereby maximizing the borehole interval drilled per bit.

4) Reduced cost of drilling fluids: drilling fluids saturated with solids that cannot be removed are generally disposed of. Efficient solids control reduces the volume of drilling fluid removal (pit jetting: see Table 2-1) by lengthening the life of the fluid system.

5) Reduction in water requirements: traditional dilution techniques require large amounts of water to be added to drilling fluid systems to reduce the concentration of drill solids. If the drilling fluid is totally unmanageable, then a new drilling fluid system must be made up using considerable amounts of water. Desilted drilling fluids require reduced amounts of dilution water because the buildup of fine solids is significantly reduced.

Hydrocyclones provide a simple and inexpensive method of mechanically treating drilling fluids (removal of solids) before they are returned to the borehole via the drillpipe. Hydrocyclones play a key role in keeping drilling costs down by removing drill solids cheaply. Moreover, they help the rotary drilling rigs complete operations more efficiently. The use of hydrocyclones in drilling operations is global and for drilling to great depths their use is almost mandatory.

Hydrocyclones separate drill fluid particles ranging from 15 microns to 150 microns as shown in Table 2-2 below. For separation of smaller particles, centrifuges are used; for separation of larger particles, shale shakers with fine mesh screens are used.

Table 2-2

Particle Size Removed By Associated Equipment in a Solids Control System

(After Marshall and Brandt 1978)

Shale Shaker	-	solids larger than 450 microns
Sandtrap	-	solids from 150 to 600 microns
Desander	-	solids from 45 to 150 microns
Desilter	-	solids from 15 to 45 microns
Centrifuges	-	solids from 0.5 to 15 microns

(0.001 inch = 25.4 microns)
(1.0 cm = 10,000 microns)

As noted by Ormsby (1982) hydrocyclones are positioned in a parallel arrangement when installed in solids control systems as shown in Figure 2-2. Depending on the capacity of the mud system, there can be from two to twenty desilters and desanders installed. This is necessary to ensure that all drilling fluid containing drill solids receives proper handling by the hydrocyclones. The hydrocyclone provides a greater degree of control over the size distribution of the drill solids in the mud circulation system.

Figure 2-2: Solids Removal Circuit for an Unweighted Mud System

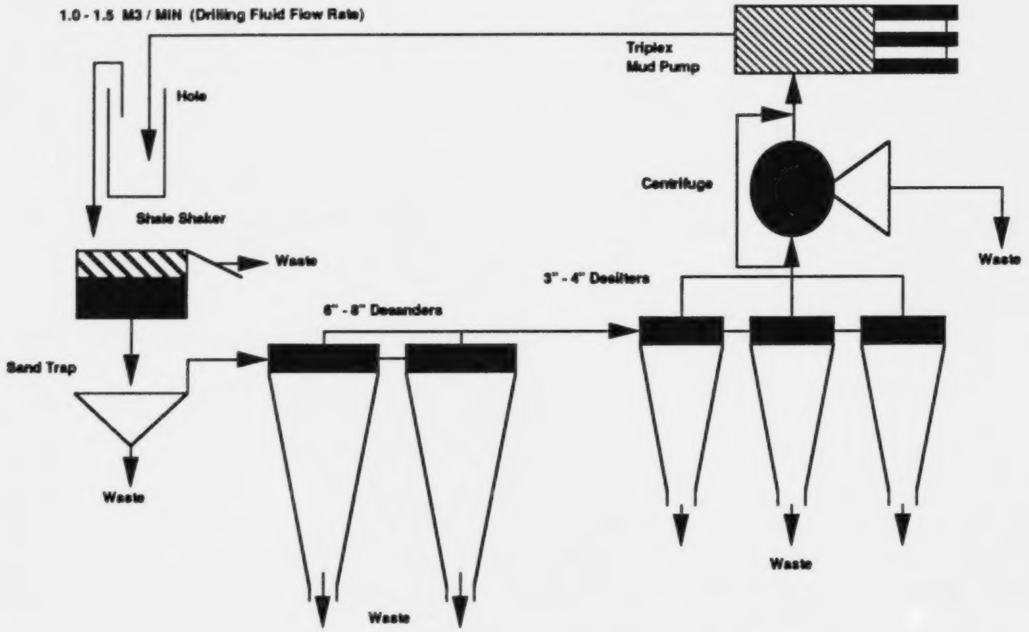
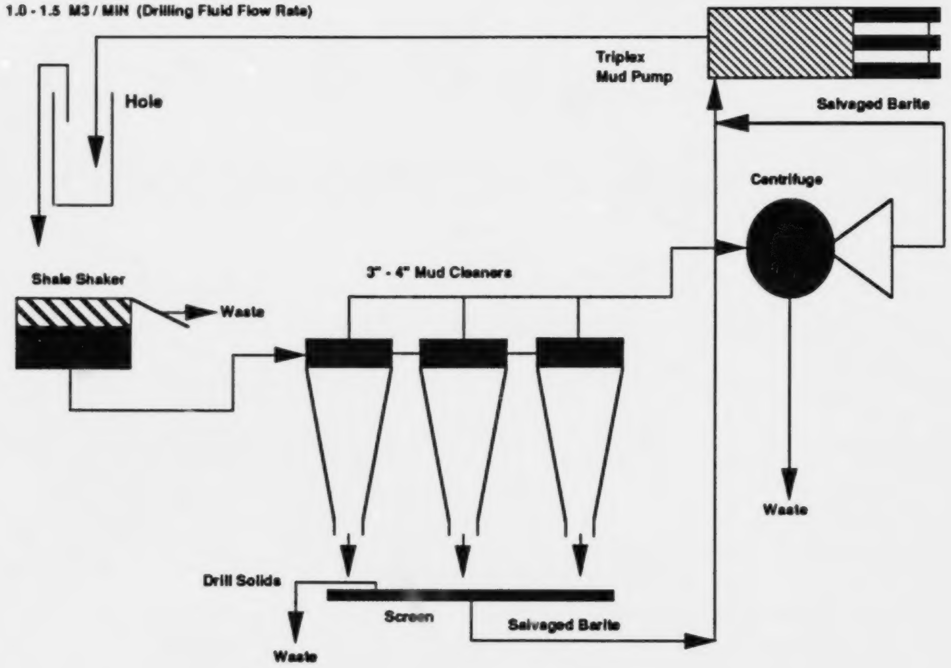

1.0 - 1.5 M3 / MIN (Drilling Fluid Flow Rate)
Triplex Mud Pump
Hole
Centrifuge
Shale Shaker
Waste
Waste
3" - 4" Desilters
6" - 8" Desanders
Sand Trap
Waste
Waste
Waste

Figure 2-3: Solids Removal Circuit for a Weighted Mud System


1.0 - 1.5 M3 / MIN (Drilling Fluid Flow Rate)
Triplex Mud Pump
Hole
Salvaged Barite
Centrifuge
Shale Shaker
Waste
3" - 4" Mud Cleaners
Waste
Drill Solids
Screen
Salvaged Barite
Waste

Although the desander is an important part of solids control systems, desilters are the most valuable among the hydrocyclones. Desilters are highly efficient at removing silt sized solids in the range 2 - 74 microns: see Table 2-3 below. Silt particles are very troublesome because they stay in the mud and are reduced in size as they circulate through the system. This silt increases mud weight as well as viscosity. The size of drilled solids in a typical drilling mud system varies from 2000 to 0.5 microns (Marshall and Brandt 1978).

Table 2-3

Classification of Drill Solids

(After Marshall and Brandt 1978)

440 microns and larger	-	large size drill solids
74 to 440 microns	-	sand sized
2 to 74 microns	-	silt sized
0.5 to 2 microns	-	clay sized
0.001 to 0.5 microns	-	colloids

2.4 Drilling Fluids

Chilingarian and Vorabutr (1981) reported that drilling fluids were first used in the petroleum industry on rotary drilling rigs some time in the late 1800's. Their intended use was to remove drill solids from the wellbore by circulating the drilling fluid down the drill pipe and up the annulus. Today, what began as a mixture of simply mud and water has evolved into a complex mixture of chemicals, water and solids.

2.4.1 Purpose of Drilling Fluids

In addition to transporting drill cuttings out of the borehole, drilling fluids are required to perform a multitude of tasks: lubricating and cooling the drill bit and drill pipe; suspending cuttings when circulation is stopped; controlling sub-surface pressures via fluid density and building a filter cake to seal off permeable formations.

2.4.2 Unweighted Drilling Fluids

Water and oil are the two types of base fluids used in unweighted muds (Chilingarian and Vorabutr 1981). A water-based mud is a drilling fluid whose continuous phase is composed of water, whereas an oil based mud has diesel or crude oil as its continuous phase. The most commonly used drilling fluid systems are water based because of cost, environmental concerns and safety, in comparison to oil based muds.

The primary ingredient in unweighted muds is bentonite, which is a clay-based material with thixotropic characteristics. The absolute density of pure bentonite is 2.50 g/cm^3. Bentonite gels the drilling fluid when circulation is stopped, thereby helping the removal of drill cuttings from the wellbore by keeping them suspended. Bentonite-sized particles are usually less than two microns in diameter and are added to obtain the required viscosity of the mud. Viscosity and gel strength are two of the properties of mud that provide a measure of hole cleaning; the addition of bentonite increases the magnitude of both of these properties.

2.4.3 Weighted Drilling Fluids

In the case of weighted drilling fluids, barite ($BaSO_4$) is added to increase the system specific gravity. As detailed by Robinson (1975), a density increase is sometimes necessary to overcome abnormally high formation pressures that may arise during drilling operations such as drilling deep high pressured gas formations. Barite has an absolute density of approximately 4.0 g/cm^3, and increases the hydrostatic head of the annular column. In weighted muds, the size of barite particles, meeting API specifications, must be between 2 and 74 microns for 80-90% of the bulk weight.

2.5 Weighted and Unweighted Solids Control Systems

Two types of solids control systems are currently used in drilling operations. One system is for weighted drilling fluids, and the other system is for unweighted drilling fluids. As noted by Ormsby (1965) the only difference between the two systems is the barite contained in a weighted mud. Hydrocyclones are used to separate solids in both weighted and unweighted systems; however, there are some differences in the approach taken in regard to solids control. Each system requires the use of separating units such as shale shakers, sandtraps, degassers, desanders, desilters, mud cleaners, screens and centrifuges: see Figures 2-2 and 2-3. Desander sizes range from 6" to 8" in diameter, while desilters range from 3" to 4" in diameter. Mud cleaners, which are desilters with a fine mesh screen attached to the underflow (Figure 2-3) are used in the weighted systems to separate the barite from the unwanted drill solids. In a weighted system, drill solids with sizes greater than 74 microns (usually the largest diameter of the barite particles) are removed by the shale shaker and the mud cleaner. When the solids and barite are removed at the underflow, the fine mesh screen separates the barite and produces a waste stream of the drill solids.

Mud cleaners are most effective when used immediately after the barite is added to the mud system as noted by Havenaar (1958). This approach ensures that the barite is separated at the earliest possible time. In this situation the drill solids are also removed before they are further broken down to silt and clay sized particles, which would make them more difficult to remove. The majority of overflow from a mud cleaner is sent to waste, while the remainder typically goes to decanting centrifuges which separate out the barite. Underflow from the mud cleaner screens is then processed by centrifuges to retrieve the barite.

When the drilling fluid initially comes out of the borehole and flows into an unweighted mud treatment system, it goes through the shale shaker first (Ormsby and Young 1983). The screens used on shale shakers are as fine as possible (usually 100 mesh screens), to remove a maximum volume of cuttings at this point. The more effectively solids are removed at this point, the easier it is for the remaining equipment to handle the remaining solids. Hydrocyclones are used in mud circulation systems because the size of separation is too fine to be carried out with standard mesh screens (typically the case from the start of the drilling operation). The overflow from the shale shaker goes directly to the sandtrap. This is the first compartment of the unweighted mud circulating system. Fluid allowed through the shale shaker proceeds to the sandtrap; the solids then settle to the bottom. Sandtrap walls typically facilitate efficient solids discharge from the bottom when tanks are being cleaned. Mud exiting the sandtrap may then be directed to a degasser where formation gases in the mud are removed. This step is made only if drilling is proceeding through known gas-bearing zones. All gases must be removed at this stage because downstream separation equipment can not efficiently function with gas in the drilling fluid because of cavitation. The drilling fluid then proceeds to the desanders and desilters for the removal of sand and silt sized drill cuttings. The underflow generally goes to waste with the overflow going to the mud pump. A small percentage of the fluid generally flows through a decanting centrifuge for the separation of the finest drill cuttings. Most drilling rigs carry one or two centrifuges for solids separation; however, the total flow rate of the system is not exposed to centrifuges because they cannot handle the total volume of the system.

Summarizing, the unweighted mud solids control systems consist of three main stages: a shale shaker which removes the coarse particles, a degasser where formation gases are removed and a centrifugal (desilting) stage where separation splits the fluid into a low-density overflow stream and a high-density underflow stream. Once the separation is complete, the mud proceeds back down the drill pipe via the mud pump.

Hydrocyclones form an integral part of any solids control system, whether in weighted or unweighted drilling muds. Optimum design and selection of hydrocyclones allows for the most efficient removal of solids, while leaving the system with minimal loss of any weighting material (barite). Centrifuges remove the smallest of the drill solids; however, they are costly and a single centrifuge is frequently unable to manage whole mud systems (depending on hole size and drilling speed).

CHAPTER III

LITERATURE REVIEW

3.1 Introduction

Hydrocyclones have been used for almost a century in the separation of liquid, solid and gas solutions. Svarovsky (1984) notes that the original hydrocyclone patent was granted in the United States in 1890. Several patents followed in the early 1900's, but none were extensively exploited.

Bradley (1965) notes that the Dutch State Mines introduced the hydrocyclone to the mineral processing industry in the late 1930's. There, hydrocyclones were used in heavy-medium coal washing operations. Their application in the mineral processing industry was that of a classifier, but, instead of using just water, they used a slurry made of finely divided magnetite in water to help achieve the specific gravity difference needed for separation. This marked the beginning of hydrocyclone use for gravity separation. Other countries such as the United States, Great Britain, France and South Africa followed suit and began using hydrocyclones in their coal washing operations.

3.2 Vortex and Flow Descriptions

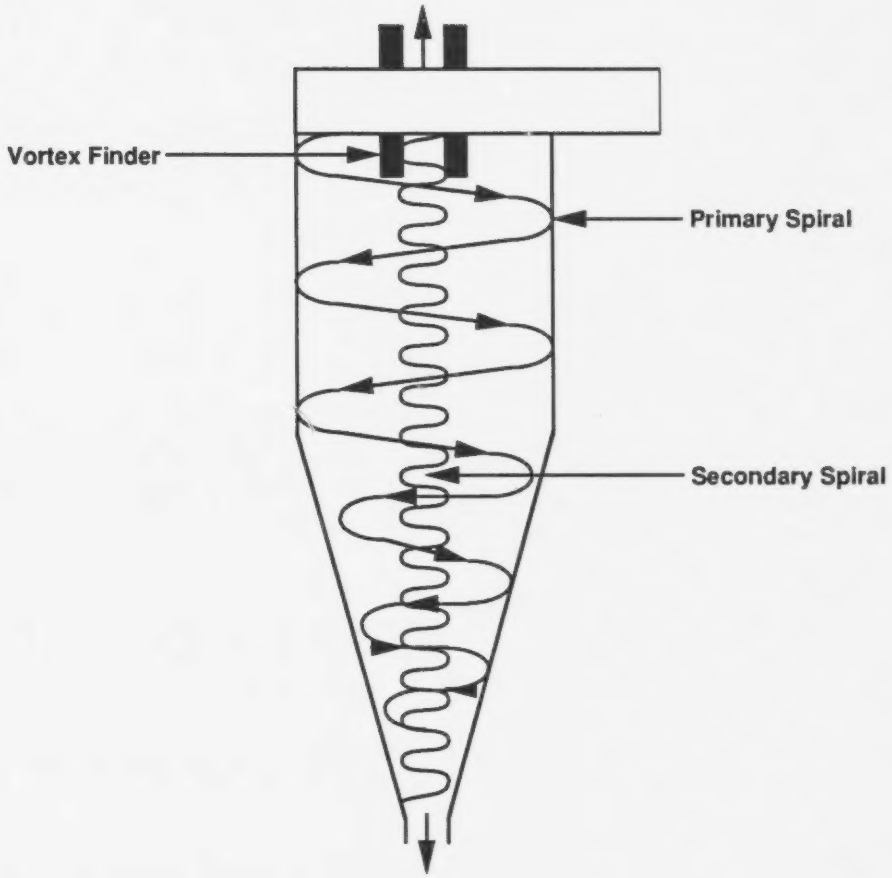
A thorough description of hydrocyclone behaviour requires discussion relating to separation mechanisms, particle settling characteristics and internal flow patterns. The work outlined next describes these phenomena and is limited to the discussion of conventional hydrocyclones only.

3.2.1 Primary/Secondary Vortex

There are two rotating spirals (vortices) in an operating hydrocyclone. One is known as the primary spiral while the other is called the secondary spiral. Both spirals rotate in the same direction (see Figure 3-1); however, their direction of motion is opposite. Upon entering the feed inlet, the slurry (pulp) starts to rotate, resulting in the formation of a primary vortex along the inside surface of the hydrocyclone wall. The primary vortex proceeds down the wall towards the underflow opening as described by Trawinski (1976). As the process progresses, the primary vortex carries the coarse particles out the apex (underflow), while the fine particles leave with the bulk of the fluid through the vortex finder (overflow).

A significant percentage of the solids leaves the apex when the hydrocyclone is operating properly. Most of the liquid is cleaned by the settling of the solids in the primary vortex. The cleaned liquid, which is carrying residual fine particles, becomes constricted towards the converging lower portion of the hydrocyclone. Inward migration increases as the cone apex is approached. The slurry, which flows in this stream, reverses its direction and flows upwards to the hydrocyclone overflow. Trawinski (1976) noted that the

Figure 3-1: Schematic Representation of the Two Rotating Spirals


Vortex Finder
Primary Spiral
Secondary Spiral

(DIAGRAM NOT TO SCALE)

secondary vortex is created at this point, and with it the fluid is forced to leave the hydrocyclone through the overflow. This, combined with the rotational motion to which it is constrained, creates the secondary vortex. The secondary vortex rotates in the same direction as the primary, but it rotates around the centre of the hydrocyclone and moves in an upward direction. The secondary vortex carries the cleaned fluid towards the vortex finder and out through the overflow.

Trawinski (1976) indicated that the primary vortex is responsible for the majority of the separation that occurs in hydrocyclones. However, the secondary vortex has a higher circumferential speed, thereby creating higher centrifugal forces, which results also in a highly efficient secondary separation.

3.2.2 Air Core/Locus of Zero Vertical Velocity

Two other important features of flow in a hydrocyclone are the air core and the locus of zero vertical velocity. During hydrocyclone operation, strong primary vortex or spiral flow creates a low pressure area in the centre of the hydrocyclone. This results in a central air core that exists in all properly operated conventional hydrocyclones (Bradley 1965). The primary vortex and the corresponding low pressure area create a cylindrically shaped rotating free liquid surface that runs the entire length of the hydrocyclone. When both ends (vortex finder and apex) of the hydrocyclone are exposed to the atmosphere, the air core becomes air saturated. As noted by Bradley (1965), the air core is important in the operation of hydrocyclones because it is an indication of vortex stability. A good air core has a constant diameter from top to bottom. A hydrocyclone that has experienced disintegration of the air core generally has a plugged or restricted apex (underflow) opening that reduces particle separation and thereby reduces the efficiency of the operation. If the rotational flow in the hydrocyclone slows, or if the pressure in the operation is reduced, the air core begins to collapse. For a properly operating hydrocyclone, the pressure of the slurry entering the feed opening must be high enough to ensure the air core is properly established.

The outside perimeter of the hydrocyclone experiences downward flow. Towards the centre there is an upward flow. In the middle of this upward and downward flow is a locus of zero vertical velocity. This area can be described as a wall that has two currents of flow on either side that flow in opposite directions as illustrated in Figure 3-2.

3.2.3 Rope and Spray Discharge

The two most common descriptions of flow from the apex of a hydrocyclone are spray and rope discharge. These are also commonly referred to as umbrella or sausage discharge (see Figure 3-3). A hydrocyclone used as a classifier usually operates with the highest efficiency when having a spray

Figure 3-2: Locus of Zero Vertical Velocity/Air Core

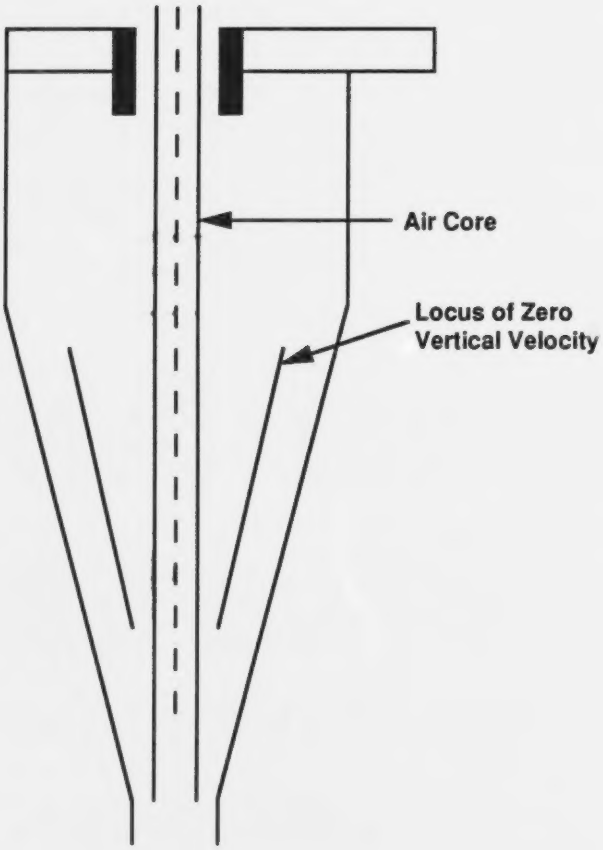
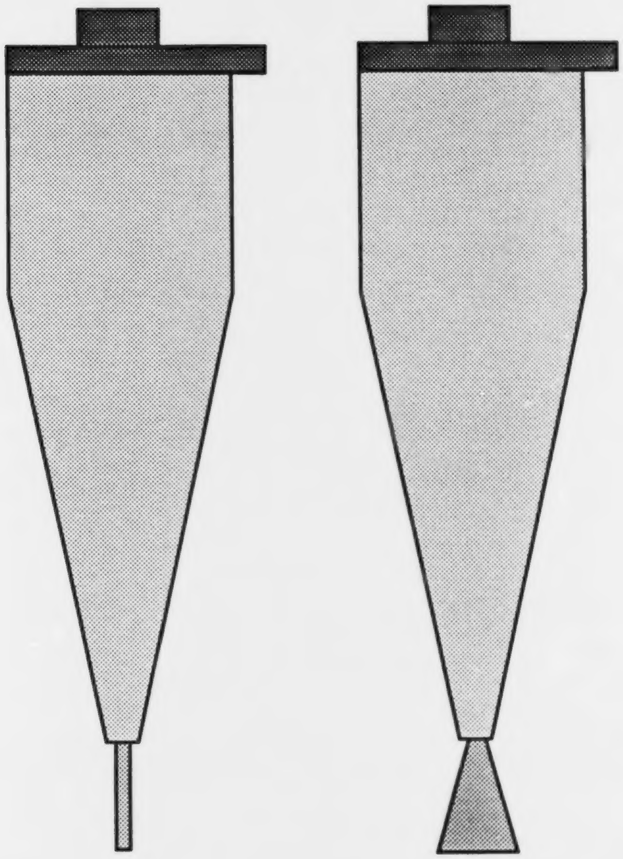

Air Core
Locus of Zero Vertical Velocity

Figure 3-3: Illustration of Rope and Spray Discharge



Rope Discharge

Spray (Umbrella) Discharge

discharge at the underflow (Bradley 1965).

When operating with a wide open underflow (open to the atmosphere), hydrocyclone discharge takes a variety of shapes depending on the separation efficiency and feed size distribution. As the concentration of solids in the underflow increases, the discharge flow condition moves from spray to rope. Under common operating conditions, where the underflow has a low concentration of solids, an umbrella or spray discharge prevails. This is a result of the high rate of spinning that occurs in the apex region of a hydrocyclone when the concentration of the feed solids is low. When the solids flow rate to the underflow increases, or when the size of the apex (underflow) is reduced, the solids concentration in the underflow stream reaches a limiting value and rope discharge results. The slurry in the underflow becomes viscous and loses its rotational motion when exiting the hydrocyclone. The stream still has a slight twist and resembles a rope. Note that for small diameter hydrocyclones the underflow risks becoming plugged if operated for any length of time under rope discharge. A blockage means that all the solids are routed to the overflow. If the roping is not quickly corrected, complete plugging of the underflow is possible.

In the case of low feed solids concentrations, Plitt et al. (1987a) illustrated that, if roping is allowed to continue in a classification operation, hydrocyclone performance is relatively unaffected by rope discharge and may even improve.

The previous discussion illustrates that careful monitoring of the underflow is critical in any hydrocyclone operation. Roping generally compromises the efficiency of hydrocyclone operations and should be avoided where feed solids concentrations are high.

3.3 Velocity Profiles

Kelsall (1952) presented the first significant study of hydrocyclone flow dynamics. Kelsall (1952) studied fluid and particle flow of an operating hydrocyclone using a method proposed by Fage and Townend (1932). The technique involved studying the motion of fine aluminum particles as they proceeded through a three-inch hydrocyclone utilizing water as the carrying medium. Kelsall (1952) made use of this optical procedure to examine the flow patterns inside a hydrocyclone of a dilute slurry containing aluminum particles.

The determination of tangential (horizontal) (V_t), vertical (axial) (V_v) and radial (V_r) velocity components associated with hydrocyclones was the significant finding of Kelsall's work. Kelsall (1952) observed that the aluminum particles had the same tangential and vertical velocities as the water. The water's radial velocity component was derived from continuity considerations. Kelsall (1952) used this information to continue investigating the methods of separation in hydrocyclones and the associated inefficiencies in hydrocyclone operation.

3.3.1 Vertical Velocity

Kelly and Spottiswood (1982) noted that the vertical velocity component V_v is a measure of the speed associated with the primary and secondary spirals as they travel downward and upward, respectively.

Kelsall (1952) determined that a particle's vertical velocity in the primary spiral reached a maximum near the cone's outer wall. As the slurry traversed towards the centre of the hydrocyclone the downward velocity was found to decrease to zero. The slurry movement then shifted upwards and increased to a maximum at the air/water (air core) interface. All liquid situated left of the locus of zero vertical velocity has an upward velocity, whereas, to the right, it has a downward velocity. This imaginary line represents the transition zone separating the primary and secondary spirals. In addition, the maximum upward vertical velocity is considerably higher than the maximum downward velocity.

3.3.2 Radial Velocity V_r

The radial velocity component, V_r, as noted by Kelly and Spottiswood (1982), represents the slurry current against which solids must settle if they are to move toward the hydrocyclone wall and down to the underflow. Radial velocity has an inward direction, increasing to a maximum value at the hydrocylcone wall. Kelsall (1952) determined that the radial velocity component decreases towards the centre of the hydrocyclone, becoming zero near the air/water interface.

3.3.3 Tangential Velocity V_t

The tangential velocity component, V_t, of the slurry is a measure of the rotating speed of the flowing medium in a hydrocyclone. As the fluid traverses towards the outer wall as the radius increases in an operating hydrocyclone, the tangential velocity decreases. Kelsall (1952) determined that the maximum tangential velocity location is at approximately 1/6 of Rc (radius of the hydrocyclone). The tangential velocity decreases slightly after this point, up to the fluid-air interface.

Kelsall (1952) was the first investigator to explain the fluid flow characteristics of an operating hydrocyclone. Bradley and Pulling (1959) also reported on the flow patterns in an operating hydrocyclone. Their study involved the injection of dye into the feed of a hydrocyclone, and the resulting flow patterns agreed with those described by Kelsall (1952).

3.4 Solids Separation Theory

In the following sections, some of the empirical and theoretical equations relating to particle separation and performance prediction for operating hydrocyclone are discussed. Definitions for all the individual terms appear in the nomenclature.

Lilge (1962) used the three velocity component system detailed by Kelsall (1952) to describe both the various paths taken by particles in the hydrocyclone and the forces associated with these paths. Figure 3-4 illustrates the main forces acting on a particle in a hydrocyclone. Lilge (1962) established a comprehensive breakdown of all the associated forces in a conventional hydrocyclone. He described how the resultant forces varied throughout the body of the hydrocyclone; specifically, from the side of the vortex finder, down to the apex of the conical section.

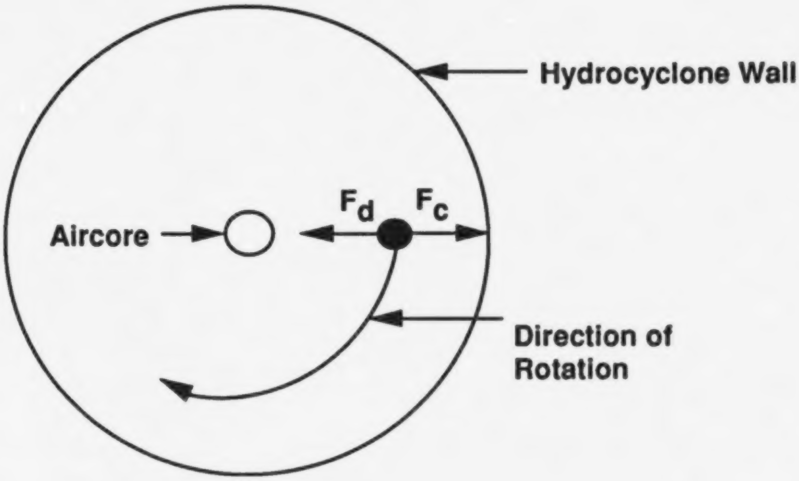
The two prevalent forces acting on particles in an operating hydrocyclone are described as:

1) Centrifugal Force (F_c).
2) Drag Force (F_d).

The drag force, F_d, pulls particles towards the centre of the hydrocyclone, whereas the centrifugal force, F_c pulls particles towards the hydrocyclone wall. Assuming that a particle in the hydrocyclone is spherical with a diameter (d), and that laminar flow conditions prevail, centrifugal and drag forces can be expressed respectively by the following two equations:

$$F_c = \frac{\pi\, d^3\, (\rho_s - \rho_f)\, v_t^2}{6r} \qquad \textbf{(3-1)}$$

Figure 3-4: The Two Main Forces Acting on a Particle Within a Hydrocyclone


Hydrocyclone Wall
Aircore
F_d
F_c
Direction of Rotation

Top View of an Operating Hydrocyclone

$$F_d = 3\pi d\mu v_r \tag{3-2}$$

where

ρ_f = *specific gravity of liquid phase*

ρ_s = *specific gravity of solids*

r = *radial orbit of the separated particle*

μ = *fluid absolute viscosity*

d = *particle diameter*

v_t = *tangential velocity*

and

v_r = *radial velocity.*

When F_c is larger than F_d, the particles settle towards the hydrocyclone wall. The opposite takes place when F_d is greater than F_c.

3.5 Hydrocyclone Performance

The performance of a hydrocyclone operation has usually been determined by the evaluation of four fundamental parameters (Plitt 1976). These are:

1) Cut size.
2) Flow split.
3) Capacity versus pressure drop relationship.
4) Sharpness of separation.

For a hydrocyclone operating as a classifier or thickener, the most important performance parameter is the resultant d_{50} value or cut size. The cut size is the particle size that has a 50% probability of going either to the underflow or the overflow during a hydrocyclone operation. The cut size is important in drilling desilter operations because a low cut size generally means that a significant amount of feed solids has been emitted to the underflow.

3.5.1 Predictive Methods For Determining the Cut Size

1) Theoretical Equations

The cut size can be predicted using empirical and theoretical equations that are based largely on the design variables of the hydrocyclone (D_u, D_o, D_i, h etc.). Other equations (both theoretical and empirical) have had fluid properties such as density and viscosity incorporated into them.

Theoretical analysis of the hydrodynamics of hydrocyclones has always been made with dilute mixtures of solids. Bradley (1965) noted that slurries containing less than 1% solids by volume are used because the solids, at such a low concentration, have negligible effect on the flow patterns in the hydrocyclone.

Although theoretical equations exist in the literature, their accuracy for predicting hydrocyclone performance is usually quite poor; however, some of these expressions are worth reviewing.

Svarovsky (1984) observed that most theoretical equations have been derived, in part, from one of three hypotheses. The three hypotheses are looked at in the next section and are followed by a discussion of some of the theoretical equations.

A) Particle Residence Time

Rietema (1961) proposed a theoretical approach based on flow regimes that stressed the importance of particle residence time to estimate the cut size. The residence time, as described by Rietema (1961), was the time a specific particle stayed in the hydrocyclone prior to its separation.

One of Rietema's (1961) major assumptions in developing this theory was that no hindered settling occurred in the operating hydrocyclone. Most researchers, like Kelsall (1966), considered this assumption invalid. Their reasoning was that classification is a direct result of hindered settling. Coarse particles in the underflow always contain fine particles of material because of inefficiencies associated with hydrocylcone separation.

B) Hypothesis of Crowding

The hypothesis of crowding was first postulated by Fahlstrom (1963) and was used to explain the separation of solids with a high concentration in the feed. According to this theory, separation was due to hindered settling and hindered discharge through the apex. The hydrocyclone separates particles efficiently through the two discharge orifices but only emits coarse particles up to the capacity limit of the underflow. The capacity limit is determined mostly by the diameter of the apex or underflow.

C) Equilibrium Orbit Hypothesis

In developing theoretical equations to predict cut size, some investigators have used the equilibrium orbit hypothesis to help develop their respective equations. This hypothesis, developed by Lilge (1962), balances the centrifugal force equation, (3-1), with the drag force equation, (3-2). When the two forces have an equal effect on a specific particle, the size of that particle is the cut size of the hydrocyclone operation. Using the equilibrium orbit hypothesis mentioned above, the following theoretical equation for predicting the cut size is obtained:

$$d_{50} = \sqrt{\frac{18\mu v_r r}{(\rho_s - \rho_f)\, v_t^2}} \qquad \textbf{(3-3)}$$

where

μ = *absolute viscosity of fluid*

r = *radial orbit distance of* d_{50} *particle*

v_r = *radial velocity*

v_t = *tangential velocity*

ρ_f = *fluid density*

and

ρ_s = *solid density.*

Bradley (1958) formulated a very complex equation based upon particle movement according to Stokes' Law:

$$d_{50} = 2.7 \left(\frac{\tan\frac{\theta}{2}\ \mu\ (1 - R_v)^{0.5}}{D_c Q\ (\rho_s - \rho_f)}\right) \left(\frac{2.3 D_o}{D_c}\right) \left(\frac{D_i^2}{\alpha_i}\right) \qquad \textbf{(3-4)}$$

where

α_i = *parameter dependent on design and fluid properties*

R_v = *volumetric fraction of feed leaving underflow*

θ = *cone angle*

D_c = *diameter of hydrocyclone*

D_o = *diameter of vortex finder*

μ = *absolute viscosity*

and

Q = *flowrate.*

Lilge (1962) postulated an expression that correlated various hydrocyclone parameters including cone particle size, radial and tangential velocity and the densities of the liquid and solid mediums. He evaluated the geometry and particle dynamics that were generated in the hydrocyclone and developed the cone force equation given below:

$$(\rho_s-\rho_f)\ d\ \frac{V_t^2}{r_t} = C_D\ \rho_f\ \frac{V_r^2}{2} \qquad \textbf{(3-5)}$$

where

C_D = *drag coefficient*
V_t = *tangential velocity*
V_r = *radial velocity*
r_t = *radius of cone where* V_t *is measured*

and

d = *particle size.*

After determining the maximum tangential velocity, v_t, along with the corresponding radial velocity, v_r, the equation can be used to determine the size of particle that reports 50% to the underflow and 50% to the overflow. Solving for d results in the cut size value.

Pericleous and Rhodes (1985) developed a mathematical model for a hydrocyclone classifier that predicted the cut size using numerical techniques. Their method of solving for d_{50} was to solve a series of differential equations; the results were not generally close to cut size values derived by empirical methods, such as those of Lynch and Rao (1975) and Plitt (1976).

2) Empirical Cut Size Equations

The most successful method of predicting cut size has come from equations derived empirically by regression analysis and curve fitting techniques. Investigators have performed numerous experiments using hydrocyclones with both large and small diameters with varying overflow, underflow and inlet diameters to accumulate an abundance of cut size values. Empirical equations have then been generated by curve fitting the cut size values to expressions incorporating the various design variables and flow properties of hydrocyclones. Some of these expressions are discussed in the next section.

Dahlstrom (1954) proposed the following empirical equation for cut size using data generated from a 22.8 cm hydrocyclone:

$$d_{50} = 81 \frac{(D_o D_i)^{0.68}}{Q^{0.53}} \left(\frac{1.73}{\rho_s - \rho_f}\right)^{0.5} \qquad \textbf{(3-6)}$$

where

d_{50} = (*microns*)

D_0, D_i = (*inches*)

Q = (*US gallons*/min.)

and

ρ_s, ρ_f = (g/cm^3).

Yoshika and Hotta (1955) developed the following expression for the cut size using hydrocyclones with diameters ranging between 7.62 and 15.24 cm:

$$d_{50} = \frac{63{,}000\ D_c^{0.1}\ D_i^{0.6}\ D_o^{0.8}\ \mu^{0.5}}{Q^{0.5}\ (\rho_s - \rho_f)^{0.5}} \qquad \textbf{(3-7)}$$

where

d_{50} = (*microns*)

D_c, D_0, D_i = (*meters*)

Q = (*Litres/sec.*)

ρ_s, ρ_f = (g/cm^3)

and

μ = *centipoise.*

Bradley (1965) derived the following equation for d_{50} cut size:

$$d_{50} = 4.5 \left(\frac{D_c^3 \mu}{Q^{1.2} (\rho_s - \rho_f)} \right)^{0.5} \qquad \textbf{(3-8)}$$

where

d_{50} = (*microns*)

D_c = (*cm*)

μ = *viscosity* (*centipoise*)

Q = *flow rate* (*Litres*/min.)

and

ρ_s, ρ_f = (g/cm^3).

Lynch and Rao (1975) studied operating characteristics such as the throughput, vortex finder diameter, solids content of the feed and the feed pressure. They derived the following equation for the cut size using slurries in their experimental work that had a solids content ranging from 15 to 70 percent.

$$\begin{aligned} Log_{10}\, d_{50} &= 0.04\, D_o - 0.0576 D_u + 0.0366 D_i \\ &+ 0.0299 \phi_s - 0.0001 Q \end{aligned} \qquad \textbf{(3-9)}$$

where

d_{50} = (*microns*)

ϕ_s = (*percent*)

Q = (*mL*/min)

and

ρ_s, ρ_f = (g/cm^3).

Another equation relating the corrected cut size to operating parameters and feed conditions was that by Apling et al. (1982). The regression expression was shown as:

$$d_{50c} = \frac{1316\ \exp(\phi_s\ 0.018\ )}{Q^{0.37}(\rho_s - \rho_f)^{0.5}} \qquad \textbf{(3-10)}$$

where

d_{50c} = (*microns*)

D_o, D_u, D_i = (*cm*)

and

ϕ_s = (*percent*).

The Apling et al. (1982) equation predicted the d_{50c} cut size, which is also known as the corrected cut size. This performance parameter is described in a later section.

In all the previously mentioned empirical equations, only the Lynch and Rao (1975) and the Apling et al. (1982) equations have a percent solids term. These two equations can be used for a wide range of solids concentrations. The other empirical equations only apply for slurries with low values of percent solids (usually less than 20 percent by weight).

3.5.2 Experimental Determination of Cut Size

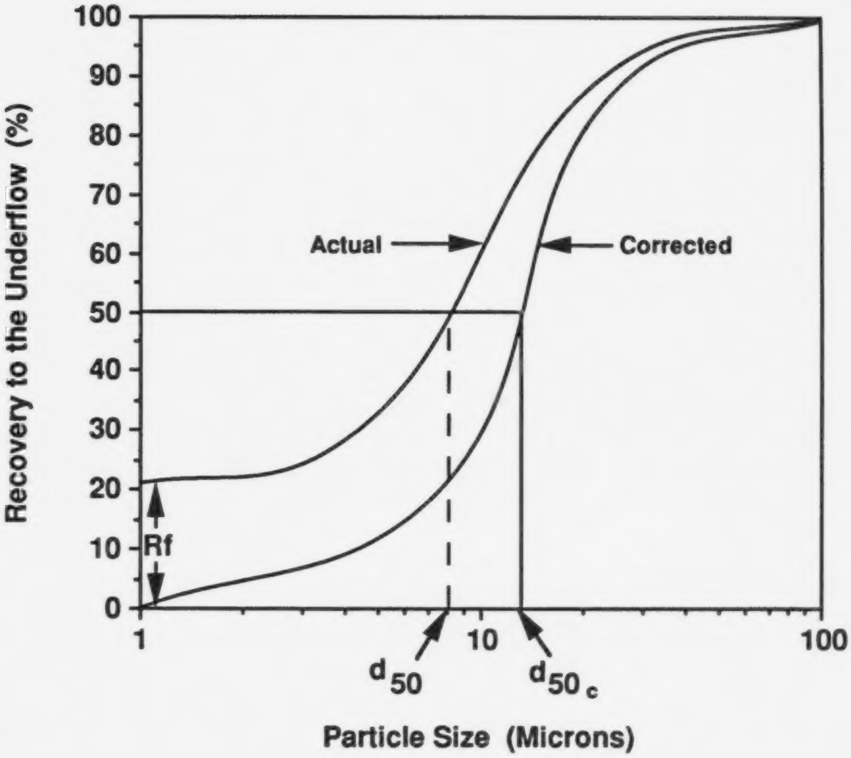
The cut size can be determined experimentally by obtaining samples of the overflow and underflow during a hydrocyclone operation, then performing a size analysis on the respective samples. A classification or partition curve can be plotted from which the cut size can be estimated.

A hydrocyclone partition curve depicts the fractional mass recovery of an average particle size range to the underflow, and was first used by Tromp (1937). This is done for each average particle size that passes through the hydrocyclone. Average particle size values are selected by the investigator generating the specific curves. Figure 3-5 depicts a partition curve for a typical classification process. For a typical mud circulation system, the desilter process can be evaluated by analyzing the underflow and overflow streams. The cut size is estimated directly from the partition curve (Figure 3-5).

Determining the d_{50} size is required information for calculating efficiency; however, classifying operations rarely operate at 100% efficiency. A correction factor must be worked into the performance calculations. This correction factor accounts for the fine particles carried to the underflow with the underflow liquid. To compensate for this inefficiency, the partition curve is adjusted to determine the corrected cut size d_{50c}, as shown on Figure 3-5. The d_{50c} size is the performance parameter that Apling et al. (1982) derived that was discussed in the previous section.

Kelsall (1953) proposed that the following expression be used to establish the corrected partition curve for a

Figure 3-5: A Corrected and Uncorrected Partition Curve



classification process:

$$y_i = \frac{y-Rf}{1-Rf} \qquad \textbf{(3-11)}$$

where

y_i = *mass fraction of particles of a specified size collected at the underflow and corrected for water*

y = *mass fraction of particles of a specified size collected at the underflow*

and

Rf = *fraction of feed liquid collected at the underflow.*

The d_{50c} cut size can be determined once the values of y_i are calculated. The d_{50c} is more representative of the actual cut size that results due to classification, as this value represents the cut size of solids which have actually been subjected to the separation process.

3.5.3 Flow Split

The flow split (S) is usually defined as the volumetric flow rate of the underflow divided by the volumetric flow rate of the overflow. The flow split is of importance to desilting operations because knowledge of the liquid and solid volumes reporting to the underflow is required when optimizing a solids control system. Moreover, terms usually associated with the flow split, with respect to desilter operations, are (Rf) and (Rs). The parameter Rf, as defined previously, is the recovery (as a fraction) of feed liquid reporting to the underflow. Calculating the water recovery is very important during desilting operations because it represents the fluid that is being lost during drilling operations. The parameter Rs is the fraction of feed solids that report to the underflow. In any drilling operation using unweighted muds, the objective is to maximize the solids recovery while minimizing the water recovery.

The water recovery usually can be determined directly from a well defined partition curve, such as the one shown in Figure 3-5. In addition, it can be calculated by performing a mass balance on the fluid transferred to both the overflow and underflow. Solids recovery is typically measured experimentally by performing a mass balance on a sample of the overflow and underflow.

An expression first proposed by Dahlstrom (1949) illustrates the definition for S mentioned previously:

$$S = \frac{V_u}{V_o} \qquad \textbf{(3-12)}$$

where

V_u = *volumetric flowrate of underflow*

and

V_o = *volumetric flowrate of overflow.*

The flow split S can be evaluated from any of the combinations of the three flow streams associated with standard hydrocyclones (feed, overflow and underflow).

Several empirical correlations exist that define the flow split for hydrocyclone operations as discussed by Bradley (1965) and Lynch and Rao (1975). Correlations usually take the form of:

$$S = k\ (\frac{D_u}{D_o})^n \tag{3-13}$$

The values of k and n in Equation (3-13) are dependent upon the hydrocyclone's geometry and inflow feed properties.

3.5.4 Capacity versus Pressure Drop

A pressure drop across a hydrocyclone results from any separation operation. As such, the pumping system must be properly designed for a specific capacity. Note that hydrocyclones generally operate between 35 - 345 kPa (5 - 50 psig). The size of the hydrocyclone, specifically the diameter, dictates the feed pressure requirement for an operation. The larger the hydrocyclone, the lower the operating pressure. Moreover, desilters operate between 138 - 345 kPa (20 - 50 psig) because of their small diameter.

Sufficient supply pressure (feed head) is required to ensure sufficient tangential velocity into the inlet, thereby creating the centrifugal forces required for particle separation. These pressure and capacity variables are interdependent so an increase in pressure results in an increase in throughput. However, excessive hydrocyclone wear results if operating pressures are too high. A general expression relating flow rate and pressure drop has been presented (Plitt 1976 and Lynch and Rao 1975):

$$Q = k(P)^{n} \qquad \textbf{(3-14)}$$

where

Q = *flow rate*

P = *pressure drop*

and

K/n = *constants dependent upon hydrocyclone geometery and slurry properties.*

Generally, higher hydrocyclone operating pressures result in the following:

1) Reduced cut sizes (d_{50} and d_{50c}).
2) A decrease in liquid recovery to the underflow (Rf).
3) An increase in solids recovery to the underflow (Rs).

3.5.5 Sharpness of Classification

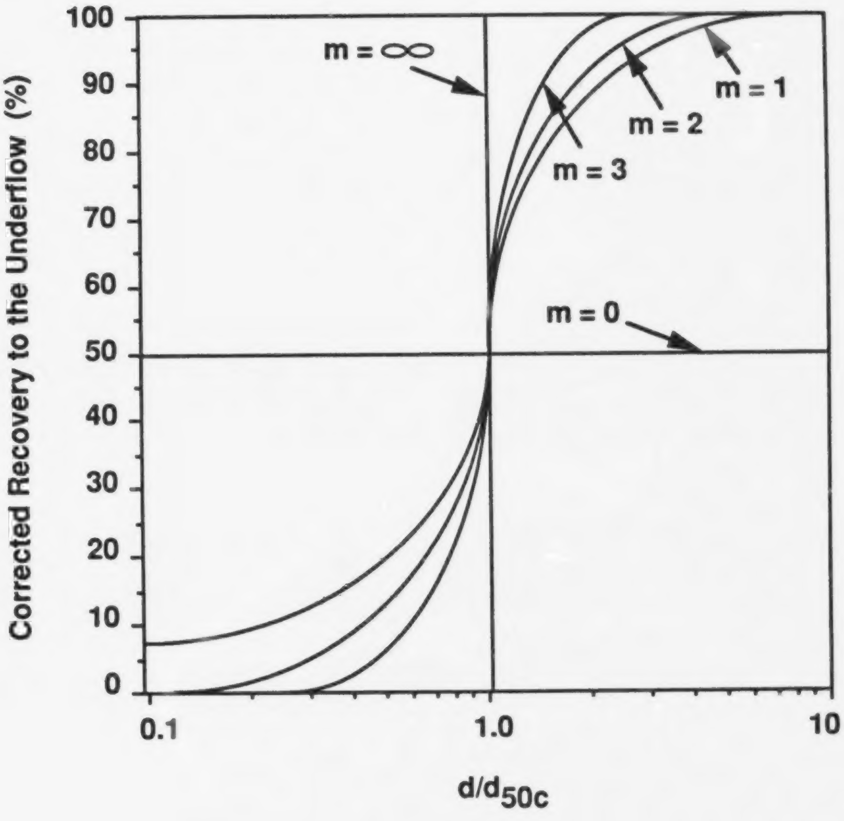
Sharpness of classification (separation) refers to the ability of a hydrocyclone to separate the coarse solids from the fine solids (also known as sharpness of cut). Recall that the object of classification is to have an underflow containing a minimum of fines and an overflow with a minimum of coarse solids. As presented in the literature, sharpness of separation has been defined by the variable m. This variable is a measure of the sharpness relating to the partition curve, as illustrated in Figure 3-6. As noted by Plitt (1971), the steeper the slope of the partition curve, the sharper the separation. There is no classification when m is equal to zero, and there is perfect classification when m is equal to infinity. Note that values of m typically fall between 1 and 3 for most hydrocyclones.

It is also common to use a term called the probable error, as discussed by Plitt et al. (1980), when describing the sharpness of separation. The probable error is defined as:

$$E_p = \frac{d_{75c}-d_{25c}}{2} \qquad \textbf{(3-15)}$$

Note that the d_{75c} size is the corrected cut size for fractional recovery at 75%, and the d_{25c} size is the corrected cut size for fractional recovery at 25%. Both of these cut size values are estimated from corrected partition curves by simply finding the corrected recoveries of 25% and 75% and reading off the resultant particle size value. The ratio of the probable error to the d_{50c} size is the imperfection of the classification curve as described by Plitt et al. (1980). The imperfection of a corrected classification curve is defined as:

Figure 3-6: Illustration of The Sharpness of Classification



$$I = \frac{E_p}{d_{50c}} = \frac{d_{75c}-d_{25c}}{2d_{50c}} \qquad \textbf{(3-16)}$$

Imperfection values typically range from 0.2 to 0.8 and have a mean value of roughly 0.3. The "m" and "I" values have been related by a simple approximation (Plitt et al. 1980):

$$I \approx \frac{0.77}{m} \quad for\ 1.1 < m < 3.5 \qquad \textbf{(3-17)}$$

A more precise expression relating m and I is:

$$I = \frac{2^{\frac{1}{m}} - 0.415^{\frac{1}{m}}}{2} \qquad \textbf{(3-18)}$$

It is important to note that Equation (3-18) was used in determining m values for the partition curves generated in this investigation.

3.5.6 Performance Curve Equations

There are three commonly used empirical expressions that define and model partition curves. All three performance curve equations represent partition curves effectively. These expressions are as follows:

1) Plitt-Reid Equation (Plitt 1971 and Reid 1971):

$$y_i = 1 - \exp\left(-0.693 (d_i/d_{50_c})^m \right) \qquad \textbf{(3-19)}$$

2) Lynch Equation (Lynch 1975):

$$y_i = \frac{\exp(\alpha\ d_i/d_{50_c}) - 1.0}{\exp(\alpha\ d_i/d_{50_c}) + \exp \alpha - 2.0} \qquad \textbf{(3-20)}$$

$\text{where } \alpha \approx 1.54m - 0.47$

3) Lilge-Plitt Equation (Lilge and Plitt 1968):

$$y_i = \frac{1}{1 + \left(\frac{1}{d_i/d_{50_c}}\right)^m} \qquad \textbf{(3-21)}$$

Equation (3-11) can be written to describe the mass fraction of particles which report to the underflow (Plitt 1991):

$$y = y_i\ (1.0 - Rf) + Rf \qquad \textbf{(3-22)}$$

Substituting Equation (3-19) into Equation (3-22) results in the following expression.

$$y = (1 - \exp(-0.693\ (\frac{d_i}{d_{50_c}})^m)\ (1 - Rf) + Rf \qquad \textbf{(3-23)}$$

Equation (3-23) represents the standard form of the Plitt model for modelling the partition curve of a hydrocyclone classifier.

3.6 Mathematical Models

It is important to be able to predict accurately hydrocyclone performance changes that may occur with changes in feed parameters such as flow rate, pressure and particle size distribution, or, in hydrocyclone dimensions, D_i, D_o, D_i and D_c. A mathematical model usually encompasses equations that predict the four major performance parameters as described in the last section.

Hydrocyclone modelling has been investigated on both empirical and theoretical levels over a number of years (Plitt et al. 1987b). Recent work done on empirical modelling includes that of Vallebuona et al. (1994) using small diameter hydrocyclones (2.5 - 5.0 cm in diameter). Vallebuona et al. (1994) evaluated the predictive accuracy of two well known empirical models, that is, Plitt (1976) and Lynch and Rao (1975). They used copper flotation tailings as a slurry.

Numerical simulation with advanced computers has initiated new studies of mathematical modelling from the theoretical side. As previously mentioned, Pericleous and Rhodes (1985) used numerical simulation techniques to model hydrocyclone performance equations. Moreover, Brayshaw (1990) developed a numerical model for the inviscid flow of a liquid in a hydrocyclone to show the effects of flow dynamics on particle classification.

These theoretical models are based on operating hydrocyclone flow dynamics. They are also difficult to develop due to the complexity of fluid flow in hydrocyclones. However, empirical hydrocyclone performance prediction models have proven to be more reliable than the theoretically based methods. In fact, the two recent theoretical models mentioned above were validated by comparing their predictive results with the results generated by empirical methods. This illustrates the need for continued research aimed at understanding hydrocyclone flow characteristics.

3.6.1 The Plitt Model

Plitt (1976) empirically developed four expressions which described specific hydrocyclone operating parameters. These expressions were the corrected cut size (d_{50c}), volumetric flow split between the overflow and underflow (S), volumetric throughput or pressure (Qi and P) and the sharpness of separation (m). All equations proposed by Plitt (1976) were written in terms of operating and design variables of the standard hydrocyclone used in mineral processing operations. Note that the model was developed using some of the experimental data published by Lynch and Rao (1975). The equations presented by Plitt (1976) were as follows:

1) Corrected Cut Size (d_{50c}):

$$d_{50c} = F_1 \frac{39.7\, D_c^{0.46}\, D_i^{0.6}\, D_o^{1.21}\, \mu^{0.5} \exp(0.063\phi)}{D_u^{0.71}\, h^{0.38}\, Q^{0.45}((\rho_s - \rho_L)/1.6)^K} \quad \textbf{(3-24)}$$

where

d_{50c} = (*microns*)

D_c, D_i, D_u, D_o = (*cm*)

h = (*cm*)

Q =(*Litres*/min.)

ρ_f , ρ_s = (*g*/*cm*^{3})

μ = *apparent viscosity* (*centipoise*)

ϕ = (*percent*)

k = 1.0

and

F_1 = *calibration factor* (*default value* = 1.0).

2) Flow Split (S):

$$S = F_2 \frac{1.9(D_u/D_o)^{3.31} h^{0.54} (D_u^2 + D_o^2)^{0.36} \exp(0.0054\phi)}{H^{0.24}\;\; D_c^{1.11}} \quad \textbf{(3-25)}$$

where

S = *dimensionless*

H = *pressure drop expressed as head* (*m*)

and

F_2 = *calibration factor* (*default value* = 1.0).

3) Pressure (P):

$$P = F_3 \frac{1.88\ Q^{1.78} \exp(0.0055\phi)}{D_c^{0.37}\ D_i^{0.94}\ h^{0.28}\ (D_u^2 + D_o^2)^{0.87}} \qquad \textbf{(3-26)}$$

where

F_3 = *calibration factor* (*default value* = 1.0).

4) Sharpness of Classification (m):

$$m = F_4\ 1.94 \exp\left(-1.58 \frac{S}{S+1}\right) \left(\frac{D_c^2\ h}{Q}\right)^{0.15} \qquad \textbf{(3-27)}$$

where

F_4 = *calibration factor* (*default value* = 1.0).

The calibration factors mentioned above are always set to 1.0 when no experimental data is available.

3.6.2 The Sharma Model

Sharma (1984) presented the results of an investigation that defined four non-dimensional parameters which were determined to predict the performance of an operating hydrocyclone. The parameters presented by Sharma (1984) were the dimensionless cut size (d_{50}/Dc); sharpness of separation (m); pressure drop (P) and the liquid recovery to the underflow (Rf). Sharma used unweighted drilling fluid as a solids carrying medium for his experimental work. Hydrocyclones ranging from 7.5 to 18 cm in diameter were used in the investigation.

The following empirical equations constitute the Sharma model for predicting the performance of hydrocyclone classifiers used to desilt drilling fluids.

1) Cut Size (d_{50}):

$$\frac{d_{50}}{D_c} = 94300\ (\frac{\rho_L}{\rho_s - \rho_L})^{0.528}\ (\frac{D_i}{D_c})^{2.101}\ (\frac{D_u}{D_c})^{1.04}\ \tan(\frac{\theta}{2})^{0.247}$$

$$(\frac{L_v}{D_c})^{0.311}(\frac{D_o}{D_c})^{-0.805}\exp\ 0.097\phi)\ (1-R_f)^{0.564}\ \eta^{0.236} \qquad \textbf{(3-28)}$$

where

d_{50}, D_c, D_i, D_u = *inches*

L_v = *inches*

ρ_L, ρ_s = (g/cm^3)

ϕ, *Rf* = *percent*

θ = *degrees*

and

η = *effective viscosity (dimensionless).*

2) Sharpness of Separation (m):

$$m = 4.708 \: X \: 10^{-4.0} \, \eta^{-1.086} \left(\frac{D_i}{D_c}\right)^{2.22} \left(\frac{D_u}{D_c}\right)^{-1.832} \left(\frac{D_o}{D_c}\right)^{0.691} \tan\left(\frac{\theta}{2}\right)^{-0.0923}$$

$$\left(\frac{L_v}{D_c}\right)^{0.654} \exp\,(\,0.092\,\phi\,)\;(\,1 - R_f\,)^{-3.978} \qquad \textbf{(3-29)}$$

3) Pressure Drop (P):

$$P = 3.9908 \left(\frac{D_i}{D_c}\right)^{3.86} \tan\left(\frac{\theta}{2}\right)^{0.340} Re^{0.386}$$

$$\left(\frac{D_u^{\,2} + D_o^{\,2}}{D_c^{\,2}}\right)^{-0.500} \qquad \textbf{(3-30)}$$

where

Re = Reynolds Number (dimensionless).

4) Water Recovery to the Underflow (Rf):

$$R_f = 949.55 \, \eta^{0.989} \left(\frac{D_i}{D_c}\right)^{-1.923} \left(\frac{D_u}{D_c}\right)^{5.551} \left(\frac{D_o}{D_c}\right)^{-4.134}$$

$$\tan\left(\frac{\theta}{2}\right)^{-1.245} \exp\,(-0.174\,\phi\,) \qquad \textbf{(3-31)}$$

3.7 Drilling Efficiency Using Solids Control Equipment

Considerable research has been performed which analyzed the various separation components used in drilling fluid circulation systems. Lal and Hoberock (1985) examined shale shaker performance and presented an analytical approach to the design and use of shale shakers. A solids conveyance model was developed by Lal and Hoberock (1985) which accounted for the adhesive forces associated with liquid saturated solids. Froment and Rodt (1986) investigated the performance of mud cleaners, shale shakers, desilters and decanting centrifuges. Their work showed that a corrected cut size of 15 microns, for 7.5 to 10.0 cm desilters, is not attainable for fluid systems that contain high concentrations of bentonite. Miller (1980) presented results of a field test (in a northwest Texas area known as Cotton Valley) indicating that desilters had the most favourable results when using low bentonite concentration drilling fluids. The low solids mud was achieved by using properly maintained desilters, thereby increasing penetration rates. Miller's work illustrated the importance of including desilters in solids removal systems.

Numerous researchers, including Froment and Rodt (1986), Wojtanowicz (1987), Ormsby (1982), Hayatdavoudi (1986), Nelson (1971), and Moore (1974) investigated solids control systems for weighted and unweighted muds and the importance of using desilters and desanders.

Young (1987) conducted a total of 450 tests, using one simulated drilling fluid, to study the dimensional parameters of an operating hydrocyclone. He analyzed how these parameters affected the efficiency of hydrocyclone operations. Efficiency, as defined by Young (1987), is:

$$\%SIL_c = \frac{\%SIL - R_f}{1 - R_f} \qquad \textbf{(3-32)}$$

The amount of silica solids separated (reporting to the underflow) was corrected for the amount of liquid and bentonite reporting to the underflow. Young's results outlined the proper dimensions for a desilting hydrocyclone to allow maximum recovery of drill solids and minimum water recovery (referred to as optimal separation) for a three-inch hydrocyclone. Dimensions included D_o, D_u, and D_i in relation to the diameter of the hydrocyclone, D_c. In addition, an optimum operating pressure and overflow pressure were proposed by Young (1987). The optimum flow rate into the hydrocyclone was found to range between 140 - 227 Litres/min. Young (1987) also proposed that the cone angle should range from 10 to 12 degrees.

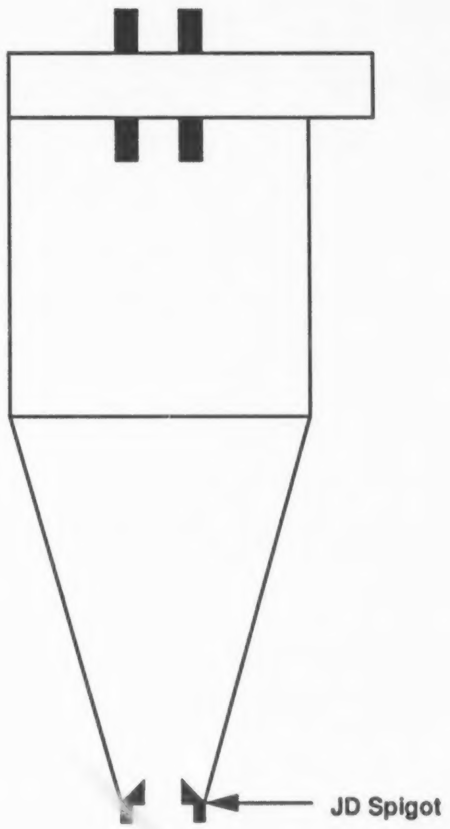
The hydrocyclone utilized in the current study followed some of the recommendations for hydrocyclone design proposed by Young (1987) (discussed later in the experimental section).

3.8 New Apex Spigot For Conventional Hydrocyclones

The JD Spigot is an underflow insert attached to the bottom of a hydrocyclone (Figure 3-7). The object of the insert is to reduce the volume of water reporting to the underflow. The JD Spigot was named after J.R. Davidson, who co-authored the initial publication regarding the device. Davidson et al. (1987) reported that proper use of the JD Spigot significantly reduced the water volume reporting to the hydrocyclone underflow when using a large diameter hydrocyclone (30.0 cm in diameter). Hydrocyclone performance was not analyzed in great detail by Davidson et al. (1987). However, for dewatering purposes (dewatering refers to the separation of liquid from the solids where the optimum result of an hydrocyclone operation is an underflow with a minimum amount of liquid recovery), the JD Spigot performed well. The JD Spigot, in comparison to regular spigots of the same diameter Du, resulted in much less water reporting to the underflow during dewatering operations.

Davis and Tuteja (1990) released unpublished preliminary results of hydrocyclone performance using the JD Spigot with large diameter hydrocyclones (25.4 cm in diameter). Two otherwise identical hydrocyclones were fitted with conventional and JD Spigots. Davis and Tuteja (1990) then performed side-by-side tests to compare efficiencies. The JD Spigot resulted in reduced amounts of water reporting to the underflow. However, the amount of solids reporting to the

Figure 3-7: A Conventional Hydrocyclone Fitted With a JD Spigot



(DIAGRAM NOT TO SCALE)

underflow also decreased. Davis and Tuteja's (1990) investigation indicated no significant differences in the d_{50} or d_{50c} of the partition curves developed using the JD Spigot and conventional spigots. Although the percentage of solids in the underflow was much higher for the JD Spigot, the sharpness of separation did not change.

3.9 Project Description

The work done to this point in this thesis has encompassed a review of the literature that discussed some of the empirical and theoretical approaches used to evaluate the performance of an operating hydrocyclone. Moreover, a discussion on separation theory and flow descriptions was also included to provide the reader with a basic introduction to hydrocyclone operations.

This review indicated that some areas of hydrocyclone performance concerning desilters used in the drilling industry warranted further investigation. Moreover, much of the understanding of hydrocyclone flow characteristics is still empirical in nature, as illustrated by the inability of theoretical based models to predict accurately hydrocyclone performance.

Two areas of investigation were proposed for this study, namely:(1) an investigation of the performance obtained using the JD Spigot installed on a small diameter hydrocyclone (7.5 cm in diameter) using both water only and bentonite drilling fluids; and (2) an investigation of the predictive capabilities of the Plitt and Sharma models with respect to determining the performance of desilters using water only and bentonite drilling fluids.

Significant opportunities exist for hydrocyclone research such as developing a theoretical model that can accurately predict hydrocyclone performance over a wide range of design configurations. However, the areas of research chosen in this study were based upon the need to evaluate the new spigot design configuration (JD Spigot) and how it could be utilized in the petroleum drilling industry. The JD spigot, when used with large conventional hydrocyclones, has shown a reduction in water reporting to the underflow. This would prove valuable to the petroleum drilling industry where a reduction in liquid reporting to waste is important. Hydrocyclone tests were initiated to evaluate the new spigot to see if it had an application in drilling fluid circulation systems.

No previous study has been undertaken to analyze the models that predict hydrocyclone performance under conditions realized during desilter operations. A comprehensive analysis should reveal the best model or equations for predicting desilter performance. This will assist drilling companies to optimize their mud circulation systems and help in scaling up a system, and predicting, based on drilling rates, what performance can be expected, using desilters for solids separation. The Sharma model was developed empirically using drilling fluids; the four equations proposed should be investigated to test their accuracy. The Plitt model has been used extensively in the mineral processing industry for the prediction of hydrocyclone performance under various operating conditions. The Plitt model is evaluated because it has received considerable attention in the literature. Moreover, the model encompasses the four main performance parameters which relate directly to desilters.

3.10 Conclusion

Numerous research activities have been initiated to gain an understanding of the separation and flow dynamics of hydrocyclones. With the continuously growing use of hydrocyclones, knowledge of this separating device is expected to expand. Theoretical mathematical expressions that predict hydrocyclone performance with a given set of initial operating parameters may be developed as a result of ongoing work and research. Unfortunately, no comprehensive theoretical models that accurately predict hydrocyclone performance are to be found in the literature. Flow patterns in a typical hydrocyclone are too complex for effective analysis. As a result, accurately predicting the performance of these devices through theoretical equations may ultimately be impossible. Hence, empirical mathematical prediction models have been widely used.

CHAPTER IV

EXPERIMENTAL SETUP AND PROCEDURE

4.1 Introduction

A number of experiments were performed in this investigation using a hydrocyclone test apparatus. A five month period was required to do the experimental work. The main objectives were to investigate the performance of desilters using JD spigots under conditions experienced in petroleum drilling operations. In addition, they were performed to gather data so a comparison could be made with results predicted by the Plitt (1976) and Sharma (1984) mathematical models. A secondary objective was to observe how JD spigots performed in comparison with conventional spigots (of equal underflow diameters) to see if the JD spigots could be used in dewatering applications when installed on small diameter hydrocyclones.

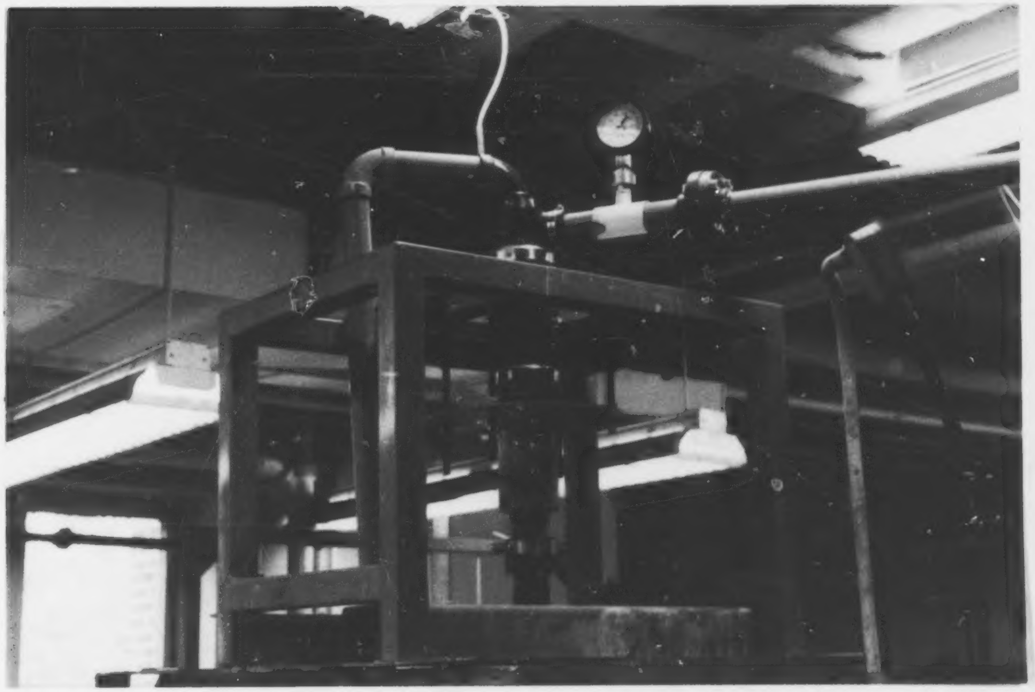
Two blends of simulated drilling fluid were used for this work: water and a mixture of bentonite and water. These fluids were selected because they are representative of the majority of drilling fluids used in current drilling operations. Water-only drilling fluids are generally used for the first 1500 m of drilling, after which bentonite gel is added to the mud system. Practical limitations allowed for the testing of these two mud systems only; weighted mud systems that included barite and other additives were not considered. To simulate solids loading conditions which occur in actual operations, it was clearly necessary to contaminate the simulated drilling fluids with solids. The solids used for this purpose were 325 mesh sand supplied by Sil Silica Ltd. of Edmonton, Alberta. A necessary requirement of this investigation was to formulate a simulated drilling fluid that contained solids similar in size and shape to those found in actual drilling fluids. The Sil Silica sand was deemed acceptable for this purpose.

4.2 Hydrocyclone Specifications

A three-inch Mozley C303 hydrocyclone was used throughout the experimental investigation. The hydrocyclone was supplied by Richard Mozley Ltd. of Cornwall, England. This type of hydrocyclone is of conventional design; Figure 4-1 displays an installed Mozley C303.

The Mozley C303 was selected because this model is pour-moulded in abrasion resistant polyurethane. Drilling fluids, both simulated and real, are highly abrasive mixtures, and polyurethane allows for optimum durability and wear. Furthermore, this unit accommodated the throughput and inlet pressure required for a typical desilter operation. In addition, Young (1987) noted that a hydrocyclone used for desilting purposes should have a cone angle of at least 10°; the Mozley C303 met this design criterion. Listed in Tables 4-1 and 4-2 are the geometric details of the Mozley hydrocyclone.

Figure 4-1: An Installed C303 Mozley Hydrocyclone



Dimensional Variables of the C303 Mozley

Nomenclature: V1, V2, V3 = Vortex Finder Names
S1, S2, S3, S4, S5, S7 = Insert Spigot Names

Extension Length = 203.2 mm
Length of Conical Section = 312.8 mm
Free Vortex Height = 516.0 mm
Hydrocyclone Diameter D_c = 74.9 mm
Cone Angle = 10 °

Table 4-1
Vortex Finder Dimensions

	D_o	D_i
V1	24.8 mm	15.6 mm
V2	17.9 mm	14.3 mm
V3	12.6 mm	12.1 mm

Table 4-2
Conventional Insert Spigot Dimensions

	D_u	h (w/o ext)	h (w/ ext)
S1	25 mm	312.8 mm	516.0 mm
S2	20 mm	312.8 mm	516.0 mm
S3	15 mm	312.8 mm	516.0 mm
S4	10 mm	312.8 mm	516.0 mm
S5	5 mm	312.8 mm	516.0 mm
S7	7 mm	312.8 mm	516.0 mm

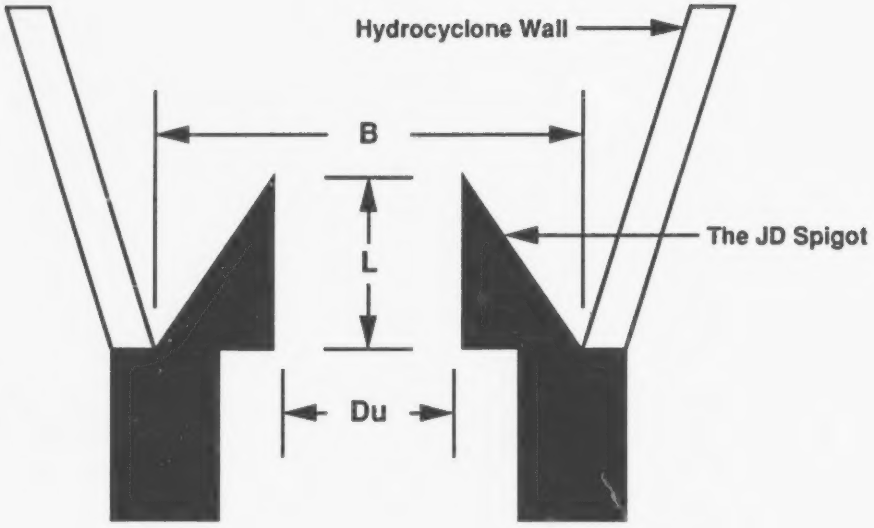
The Mozley came equipped with three vortex finders, an extension, allowing the free vortex height (h) to be changed, and six insert spigots. The vortex finders had rectangular shaped inlets; the resultant area was converted to a circular dimension to give the equivalent inlet diameter (D_i). Each vortex finder had a characteristic overflow and inlet diameter that was not adjustable.

4.3 JD Spigot Design Specifications

The only available published JD spigot literature at the start of this investigation was that provided by Davidson et al. (1987). Davidson et al. (1987) had tested JD spigots that had a larger diameter (D_c) in comparison to the Mozley C303. Specifically, hydrocyclones with a diameter of 30.0 cm and JD Spigots with an underflow diameter of 10.0 cm were tested. This investigation was the first to evaluate the use of JD spigots with small diameter hydrocyclones.

The initial JD Spigot constructed for this study was designed using an underflow diameter of 10 mm with an length (L) of 10 mm (see Figure 4-2 (note the dimensional variables B, L and D_u)). This configuration was referred to as spigot JD1, having a D_u/D_o diameter ratio of 0.4 with a vortex finder overflow diameter of 25 mm. This configuration was selected because a performance comparison could be made with conventional spigot S4, which also had an underflow diameter of 10 mm. Moreover, it was felt that spigot JD1 would have a

Figure 4-2: Basic Design of a JD Spigot (JD1)


Hydrocyclone Wall
B
L
The JD Spigot
Du

B = Base Diameterof JD Spigot
Du = Diameter of the JD Spigot
L = Length of the JD Spigot

negligible water recovery at the underflow. Therefore, it could be tested, on a comparison basis, with conventional spigots S5 and S7. Information, from the Mozley distributor stated that these spigots emitted negligible water recovery at the underflow when using a vortex finder of 25 mm.

Davidson et al. (1987) noted that JD Spigots emitted negligible water to the underflow when there was an absence of solids in the flowing medium. Ormsby and Young (1983) mentioned that a desilter should have a slow drip of water to the underflow when no drill cuttings are in the system. Spigot JD1 was designed so that it would conform to the operational specifications outlined above.

Spigot JD1 was made of stainless steel and was fabricated at the University of Alberta technical services machine shop. It was then tested with vortex finder V1 to see if it met the specifications outlined by Ormsby and Young (1983). As intended, there was just a slight drip of water to the underflow during the test. Two other JD spigots were designed, consisting of different underflow diameters (D_u) and penetration lengths (L). These were called spigots JD2 and JD3. Table 4-3 outlines the sizes or dimensions for all three JD Spigots which were considered representative of the particle size ranges to be investigated with respect to desilter operations. Spigot JD2 was built to determine

Table 4-3
JD Spigots Dimensions

	D_u	B	L	h (no/ext)	h (w/ext)
JD1	10 mm	23 mm	10 mm	302.8 mm	506.0 mm
JD2	10 mm	23 mm	22 mm	290.8 mm	494.0 mm
JD3	15 mm	23 mm	22 mm	290.0 mm	494.0 mm

JD1, JD2, JD3 = JD Spigot Names

how hydrocyclone performance changed with a larger wedge length (L). Spigot JD3 was built to determine how the performance and recovery of both water and solids (Rf and Rs) changed with the introduction of a larger D_u size using vortex finder V1. The data acquired here was intended to be compared with that obtained from conventional Mozley spigots.

4.4 Drill Solids Specifications

In order to formulate a proper drilling fluid, a field trip was conducted to obtain samples from an operating field desilter. A drilling rig (contracted by Shell Canada Ltd. in the Simonette area of N.W. Alberta) used desilters as part of its solids removal system. Samples of the desilter feed stream were obtained with Shell's permission. The samples were analyzed (see Appendix B) to determine the size breakdown of the entrained solids (see Table 4-4 below). The results were in accordance with those used by Young (1987) who outlined a size breakdown of the solids carried in a typical feed stream entering a desilter. Sil Silica Company Ltd. of Edmonton, Alberta supplied a Grade A1 (325 mesh and finer) sand that had a size breakdown that was similar to that used by Young (1987). However, the field solids (Shell's) were somewhat finer than the Young and Sil Silica solids. This was possibly a result of constant recirculation of the solids through the solids control equipment on the Shell drilling rig. The material density of the Sil Silica solids was measured to be 2.61 g/cm^3.

Table 4-4
Typical Drilling Fluid Particle Sizes

	Cumulative Percent Passing (%)		
Size (Microns)	**Literature (Young 1987)**	**Field**	**325 Mesh Sand**
106.00	100.00	100.00	100.00
74.00	95.00	100.00	98.00
63.00	85.00	100.00	97.00
53.00	94.00	100.00	93.00
45.00	89.00	100.00	89.00
34.04	76.00	98.30	84.00
23.72	65.00	95.00	70.00
15.47	55.00	73.00	52.00
11.34	42.00	64.00	45.00

4.4.1 Solids Quality Control

Water Only Drilling Fluid: A comprehensive solids sizing analysis was performed on the 325 mesh sand supplied by Sil

Silica (size analysis is discussed in detail in Appendix B). Thirty 25-kg bags were obtained; ten bags were arbitrarily chosen and sized. Results indicated that different bags had the same size distribution as the data reported for 325 mesh sand in Table 4-4. This exercise also indicated that the particle sizing technique used throughout this investigation was reproducible.

Bentonite Drilling Fluid: Bentonite from Reef Gel Inc. of Edmonton, Alberta was used in this work. Young (1987), Sharma (1984) and Moore (1974) noted that hydrated pure bentonite particles are less than one micron in diameter. Note that one micron flows freely through most sizing apparatuses. However, when the reef bentonite was gelled and sized, a 10% silt content, by weight, was discovered. Further testing indicated that all the reef gel contained a 10% silt impurity.

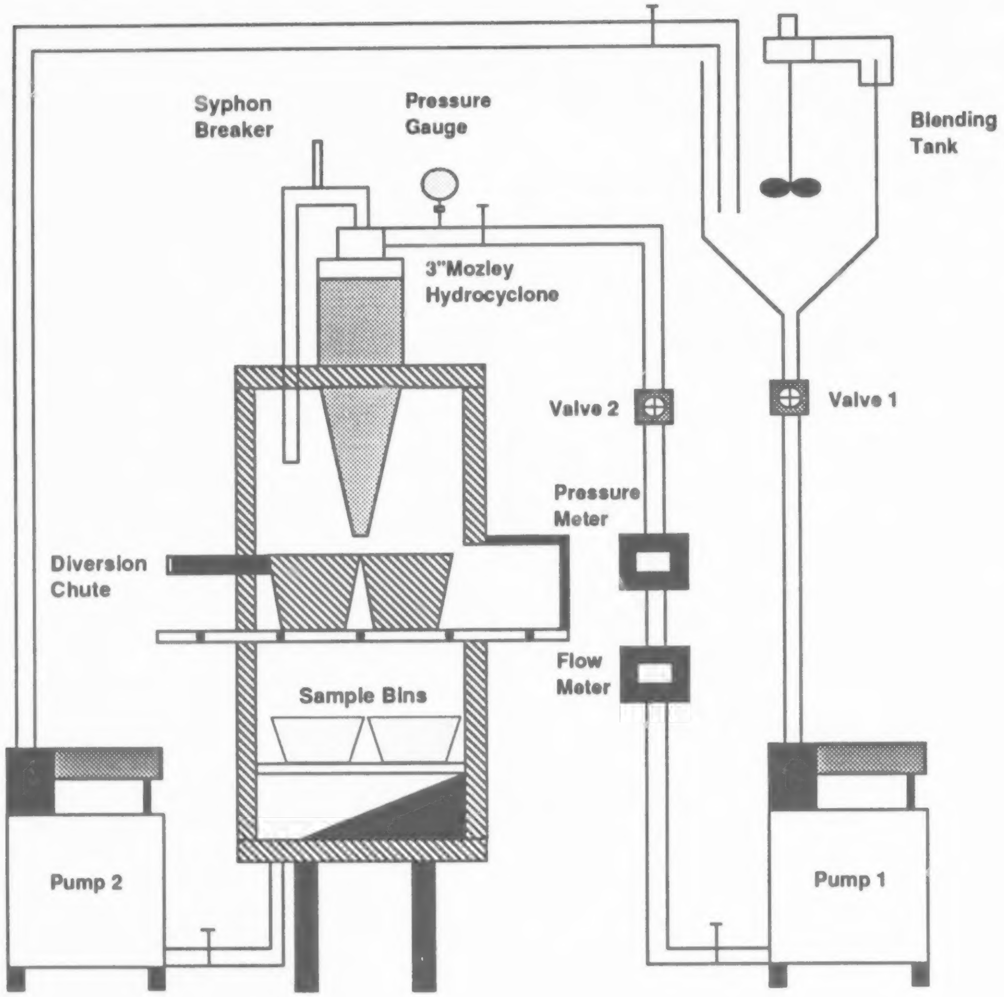
In order to determine the size breakdown of the silt impurities, four 100 g samples from different bags were mixed with 1000 mL of water. The samples were run through a sizing analysis, and they all showed a consistent size breakdown. Thus, for the simulated drilling fluid (using both sil silica sand and bentonite), the silt content of the reef gel was incorporated into the size analysis of the simulated drill solids. Depending on the amount of bentonite added for a specific run, the size distribution of the feed stream changed slightly with each adjustment in bentonite levels.

Note that pure bentonite was considered for this investigation. The petroleum lab in the department had some pure bentonite in stock and preliminary testing of this material resulted in no silt impurities. However, the price of this bentonite was prohibitive, as the anticipated testing required approximately $20,000 worth of pure bentonite. Moreover, the silt impurities in the selected bentonite were not anticipated to have any fundamental impact on the research undertaken.

4.5 The Test Apparatus

All hydrocyclone experiments were performed using the test apparatus shown in Figure 4-3. The basic components of the system included two electric motor driven pumps, a mixing tank, and a support frame for the hydrocyclone. The tank was used to mix the drilling fluid, and valves were provided in the feed flowline to control the flow rates and inlet pressures. Flow rates could also be controlled by adjusting the variable speed drive that was connected to Pump #1. The drilling fluid was kept well agitated and mixed (ensuring a homogenous slurry) by an electric stirrer mounted to the blending tank. Modifications were carried out on the original apparatus allowing for the operation of the three-inch Mozley. A special aluminum holding assembly was designed to mount the smaller three-inch hydrocyclone compared to the six-inch Krebs hydrocyclone previously installed. In addition, larger pulleys

Figure 4-3: The Hydrocyclone Test Apparatus


Syphon Breaker
Pressure Gauge
Blending Tank
3"Mozley Hydrocyclone
Valve 2
Valve 1
Pressure Meter
Diversion Chute
Flow Meter
Sample Bins
Pump 2
Pump 1

were mounted onto Pump #1 to generate a 207 kPa or higher inlet pressure to the hydrocyclone. Higher pressures were required to perform the necessary experiments as smaller hydrocyclones generally operate at higher inlet pressures. The modifications made significant improvements to the rig's ability to handle smaller diameter hydrocyclones.

4.6 Experimental Procedure

Two sets of experiments were performed in this investigation. The first consisted of a water only drilling fluid and the second a bentonite system.

The experiments were done to thoroughly evaluate the performance of hydrocyclones using JD Spigots and to provide data for modelling purposes.

First Set of Experiments:

Seventeen tests were performed in this section, each run at either 138 or 207 kPa. The percentage of silica drill solids in the feed ranged over 0%, 1%, 3% and 6% by volume. Vortex finders V1 and V2 were tested using spigots S3, S4, S5, S7, JD1, JD2, and JD3 using all four drill solids content values. Vortex finder V3 was tested with all seven of the previously mentioned spigots but at only a 3% solids concentration and 207 kPa inlet pressure. Desilters do not operate with a vortex finder like V3; however, the run was performed to supply modelling data.

The information from this set of runs was to provide information on how the JD spigots performed under the conditions experienced during the first 1500 m of a typical drilling operation.

Practical limitations meant that only the 207 kPa runs could be size analyzed. However, this does not restrict the importance of the runs done at 138 kPa because they supplied valuable recovery data.

Second Set of Experiments:

Eighteen tests were performed in this section, with the drilling fluid weights ranging from 1000 to 1068 kg/m^3 (density of the mud with only bentonite). Spigots JD2 and JD3 were not used in this series of experiments due to their poor performance in the first set (details of this are explained in the results section). However, spigot JD1 was included in the first four tests.

The goal of the second set of experiments was to determine how the JD spigot performed while using a bentonite drilling fluid. Also, the experiments supplied data for the determination of desilter performance parameters (required for modelling). In addition, some of the runs were completed to determine how the cut size changed with small incremental increases in bentonite concentration. This illustrated at which point during the addition of bentonite, the cut size becomes adversely affected. Drilling fluid systems periodically require more bentonite for various reasons. Some of the testing done here was to determine what happened to hydrocyclone performance when this happened. Note that the silt content was assumed to represent the additional drill solids so it was added into the calculation determining the percentage of drill solids in the mud.

The first three tests used vortex finder V1 along with spigots S7, S5, S4, and JD1. The inlet pressure was held at 207 kPa with the solids concentration ranging over 1%, 3% and 6% by volume. These tests were done to determine the performance of spigot JD1 using a bentonite drilling fluid. The next four tests had a drill solids concentration of 3%. Both V1 and V2 were used while the spigots were chosen arbitrarily with a different set being used for each test (results were used for modelling data).

The remaining eleven experiments had bentonite levels increased by 0.04% for each test. All tests had an inlet pressure of 207 kPa using the Mozley fitted with the extension. Vortex Finder V1 along with spigots S4, S5, S7 were used. The last four tests of this group included spigot JD1, to see how the JD Spigot would handle a high concentration of bentonite. The silica solids concentration was held at 3% for all the tests in this section.

4.6.1 Operation of the Test Apparatus

Water was circulated through the test system before any experiment began. A calibration manual accompanied the C303 Mozley. The manual outlined the percentage of water that should report to the underflow with each vortex finder and underflow spigot combination. All three vortex finders were tested along with four underflow spigots. The results reported in Appendix A were in accordance with the literature values supplied by the Mozley manual, indicating that the setup was correct. However, the system better reproduced the operations manual values when using the extension. Based on this information, the majority of the experiments were performed using the Mozley extension.

Prior to starting any experiment, a predetermined amount of water (204 litres) was added to the blending tank. The temperature of the blending tank water was checked to see if it was at, or close to, 22°C (room temperature). Kawatra et al. (1988) noted that the cut size of a hydrocyclone could fluctuate by 25% if the feed temperature changed by +/- 17°C.

To achieve the required solids content for each experimental run, the proper amounts of 325 Sil Silica sand and bentonite was added to the blending tank. The Mozley was fitted with the appropriate spigot and vortex finder for the desired test. The main feed valve was opened and the slurry then flowed into Pump #1. When the pump was close to being filled it was switched on and slurry then pumped into the feed opening of the Mozley hydrocyclone. Once it was determined that the hydrocyclone was operating properly (that is, no leaks or surging), Pump #2 was switched on so that the output could be sent back up to the blending tank. The pilot plant was allowed to operate for a sufficient period of time (usually five minutes) to attain a steady flow without any pump cavitational problems before any samples or readings were taken. The pilot plant spanned two floors in the building requiring two individuals to run the experiments.

Bentonite mud was allowed to hydrate for approximately one hour to ensure that the bentonite gelled properly. The drill solids (325 mesh sand) were then added to the slurry and allowed to mix for five minutes. The mixing blender turned slowly enough ensuring that the solid particles would not break down during the mixing procedure. A sample of the slurry (with and without silica solids) was retrieved so the density and rheological properties could be recorded. The density was measured with a weight balance while the apparent viscosity was measured with a Fann Viscometer. The apparent viscosity was used for this experimental investigation. This was due to the difficulty in establishing the exact viscosity of the bentonite drilling fluid in the hydrocyclone. The shear rate changes throughout the hydrocyclone body making it difficult to calculate a single usable viscosity. Bentonite drilling fluid is Non-Newtonian, so it behaves as a Bingham plastic. To obtain a value of viscosity, for a specific experiment, an estimation had to be done. The apparent viscosity is the 600 torque reading of the Fann Viscometer divided in half. This was certainly not the most scientific method of determining the viscosity in the hydrocyclone body. However, due to practical limitations in establishing the true viscosity, this method (for determining the apparent viscosity) was deemed acceptable for the current study. The water-only drilling fluids all had the same viscosity because water behaves as a Newtonian fluid without any additives in it. Other investigators, most notably Young (1987), used the apparent viscosity determined using a Fann Viscometer. All of the density and rheological data is outlined, in detail, in the last section of Appendix C. In addition, the 10 second and 10 minute gel strengths were recorded. The above quality control steps were done to ensure that the simulated drilling fluid reached the proper specifications for each specific experiment.

Upon entry to the inlet, the feed separated into two streams as it emerged from the hydrocyclone. The bulk of the liquid, along with most of the finer solids, passed through to the overflow. The coarser solids, containing a small amount of liquids, went to the underflow. Both of these streams were then piped to a common sump where they merged together and flowed to Pump #2. The mixture was allowed to circulate for five minutes, after which samples were retrieved from the hydrocyclone. The pilot plant was fitted with a trolley device that allowed the closed loop of the pumping circuit to be interrupted for the taking of samples. Preweighed bins were placed underneath the cyclone as shown on Figure 4-3. The hopper, which was directly under the Mozley, could be pulled backwards allowing the underflow and overflow streams to flow into two separate bins. The stream could then be directed to the bins below or to Pump #2. A stop watch was used to time the period when the flow was going into the bins. This was for approximately 3-5 seconds or until a manageable sample size was collected (usually two litres in volume).

Residue from the hopper surfaces was washed off into the bins with preweighed bottles containing water. The bottles were weighed after use to determine the amount of water washed in. This amount of water was subtracted from the respective overflow and underflow sample sizes. The bins were weighed and the amount of water used for cleaning was subtracted from the total. The bins were then placed in an oven for drying. After drying (requiring forty eight hours), the samples were weighed and placed in plastic bags for storage so they could be sized at a later date.

The water-only drilling fluids passed through the filter press easily, resulting in quick drying of the solids. The filter collected the strained solids on paper; they were then placed on pie pans and put in the drying ovens. The dried solids were brushed off, then weighed, bagged and put away for size analysis. The bentonite drilling fluid would not pass thorough the filtering device.

From the above testing procedure for both water-only and bentonite drilling fluids, Rs and Rf could be determined. Once the size analysis was completed, enough information was available to plot the individual partition curves.

CHAPTER V

EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Introduction

This chapter covers an analysis of all the experimental results obtained in this investigation. The primary objective of the experiments was to determine how the JD spigots (JD1, JD2, and JD3) performed in comparison to conventional spigots having the same underflow diameter. Moreover, a secondary objective was to test spigots JD1 and JD2 with small diameter spigots (S5 and S7) frequently used on desilters, and to determine if there was an increase in solids recovery and a decrease in liquid recovery using the JD spigots. Water-only and bentonite drilling fluids were used in the study with spigot performance separately evaluated for each drilling fluid. The main performance parameters investigated for both fluids include water and solids recovery to the underflow (Rf and Rs), cut size (d_{50}) and sharpness of separation (m). Other parameters looked at were the flow split (S), the corrected efficiency of the experiment as defined by Young (1987) (Equation 3-32), and the solids concentration of the underflow. Detailed results for all spigot tests are presented in Appendix C and D, including all recovery and partition curve data.

5.2 Water-Only Drilling Fluids

The initial experiments used a water-only drilling fluid system. The purpose of this portion of the investigation was to evaluate desilter performance using JD spigots during drilling operations with no bentonite in the drilling fluid (frequently used for the upper 1500 m of a borehole). Inlet operating pressures utilized were 138 kPa and 207 kPa (20 and 30 psig). Four different solids concentrations (0%, 1%, 3% and 6% by volume) were used along with three vortex finders (V1, V2 and V3). Vortex finder V3 was tested at one operating pressure (207 kPa) and one solids concentration (3%) for a total of seventeen tests performed. Spigots JD1 and JD2 were tested along side conventional spigots S4, S5 and S7. Spigot JD3 was tested with spigot S3. A total of 119 samples (simultaneous underflow and overflow cuts) resulted from these tests.

5.2.1 Water Recovery With Identical Underflow Diameters

Results indicated that at an inlet pressure of 207 kPa and using vortex finder V1 (D_u/D_o of 0.4), spigots JD1 and JD2 reported no water to the underflow (Rf) for a water-only system with 0% solids (see Table 5-1). Spigot JD1 did, however, report 0.3% water at 138 kPa. Spigot JD2 recovered no water at 138 kPa due to its having a longer wedge length (L) than JD1. It can be deduced that a JD spigot, having a longer length (L) dimension, has a lower water recovery value than one with a shorter length.

Table 5-2 shows the water recoveries when vortex finder V2 (D_u/D_o of 0.6) was installed in the Mozley hydrocyclone. In these tests spigots JD1 and JD2 had some water recovery to the underflow (again, spigot JD2 was less than spigot JD1). In addition, spigot JD3 had a lower water recovery value than

Table 5-1
(From Water-Only Tests #1 and #5)
Water Recovery to Underflow (Rf)
Using Vortex Finder V1 (0% Solids)

Spigot	D_u/D_o	Test #1 (207 kPa)	Test #5 (138 kPa)
S4	0.403	3.0%	5.0%
JD1	0.403	0.0%	0.3%
JD2	0.403	0.0%	0.0%
S3	0.605	13.0%	18.0%
JD3	0.605	12.0%	12.0%

Table 5-2
(From Water-Only Tests #9 and #13)
Water Recovery to Underflow (Rf)
Using Vortex Finder V2 (0% Solids)

Spigot	D_u/D_o	Test #9 (207 kPa)	Test #13 (138 kPa)
S4	0.559	13.0%	16.0%
JD1	0.559	12.0%	11.0%
JD2	0.559	10.0%	9.0%
S3	0.838	39.0%	44.0%
JD3	0.838	38.0%	37.0%

spigot S3 (each having identical underflow diameters). It is evident that, when the inlet pressure is reduced, JD spigots have a smaller increase in water recovery than obtained by the conventional spigots. They are not affected as much by the reduction in pressure drop. This is because of the wedge that protrudes up into the conical section of the hydrocyclone. The wedge acts as a hinderance to the increased flow to the underflow caused by a reduction in operating pressure. The protruding wedge of the JD spigot serves to anchor the bottom of the air core. The air core thus occupies the entire underflow opening which prevents fluid from exiting. Conventional spigots simply allow increased flow to the underflow because no obstruction is there to slow it down.

Results indicate that JD spigots reduce the water recovery to the underflow when compared to conventional spigots having identical underflow diameters. However, when the underflow diameter to overflow diameter (D_u/D_o) ratio is increased, (as when vortex finder V2 was used, or when the inlet pressure is reduced), water recovery to the underflow increases slightly using JD spigots. In some cases (as shown in Tables 5-1 and 5-2) there is no change in water recovery. Note that conventional hydrocyclones generally have higher water recovery values when the operating inlet pressure is reduced or when the ratio of underflow to overflow diameter (D_u/D_o) is increased. This has been discussed in detail by many investigators, most notably Bradley (1965) and Svarovsky

(1984). When conventional spigots operate with water only, a certain amount of water always reports to the underflow. As reported by Davidson et al. (1987), a thin film of water coats the hydrocyclone's conical section under normal operating conditions, and no mechanism inhibits a certain percentage of this water from flowing out the underflow, regardless of how small the underflow diameter is. In contrast, JD spigots have a protruding wedge section that inhibits the flow of water when there is an absence of solids in the slurry. However, when the ratio of D_u/D_o becomes high, JD spigots begin to pass some water. Davidson et al. (1987) and Davis and Tuteja (1990) performed water tests using JD spigots installed on much larger conventional hydrocyclones than the 7.5 cm Mozley used in this study. Their investigation involved hydrocyclones with diameters (D_c) ranging from 25.0 cm to 30.0 cm. Their results indicated that, as the JD spigot underflow diameter increased (while maintaining a constant overflow diameter), water recovery increased. The testing performed in this study confirms that small diameter hydrocyclones exhibit the same water recovery characteristics as do large diameter hydrocyclones when using JD Spigots. The D_u/D_o ratio that appears to be the cut off for water recovery to the underflow for a 7.49 cm hydrocyclone is 0.4 (using vortex finder V1). Under normal operating conditions (inlet pressure 138 kPa or higher) this ratio ensures that negligible water reports to the underflow. Neither Davidson et al. (1987) nor Davis and

Tuteja (1990) established a similar cut off ratio for large diameter hydrocyclones.

This investigation was the first to study the use of JD spigots on small diameter hydrocyclones. As discussed, results are in agreement with those noted by large diameter hydrocyclones in terms of water recovery.

5.2.2 Water Recovery With Differing Underflow Diameters

As noted earlier, properly operating desilters should report a slow drip of water to the underflow when there is an absence of solids in the solids control system. Spigots JD1 and JD2 met this operating specification (see Table 5-1) with their minimal water recovery values. Conventional spigots S5 and S7 (D_u/D_o of 0.202 and 0.282, respectively) reported minimal water to the underflow while using vortex finder V1. As illustrated by Table 5-3 (with an inlet pressure of 207 kPa), spigots S5 and S7 reported 0.4 and 0.9% water to

Table 5-3
(From Water-Only Tests #1 and #5)
Water Recovery to Underflow (Rf)
Using Vortex Finder V1 (0% Solids)

Spigot	D_u/D_o	Test #1 (207 kPa)	Test #5 (138 kPa)
S5	0.202	0.4%	1.0%
S7	0.282	0.9%	1.4%
JD1	0.403	0.0%	0.3%
JD2	0.403	0.0%	0.0%

the underflow, respectively (data from Water Test #1 and #5).This justified further side by side testing of spigots JD1 and JD2 with S5 and S7.

Additional testing using vortex finder V2 resulted in water recovery to the underflow increasing for all spigots (when operating at 207 kPa). In addition, when the operating pressure was reduced to 138 kPa all spigots had negligible increases in water recovery (see Table 5-4).

The higher water recovery values (going from vortex finder V1 to V2) for the JD spigots can be explained by the Du/Do ratio going from 0.4 to 0.558 when changing vortex finders. Spigots S5 and S7 cause the D_u/D_o ratio to go from 0.202 to 0.279 and from 0.282 to 0.391, respectively. The increase in the D_u/D_o ratio is larger for the JD spigots than the for conventional spigots. This explains the larger increase in water recovery for vortex finder V2.

Table 5-4
(From Water-Only Tests #9 and #13)
Water Recovery to Underflow (Rf)
Using Vortex Finder V2 (0% Solids)

SPIGOT	D_u/D_o	Test #9 (207 kPa)	Test #13 (138 kPa)
S5	0.279	2.0%	2.2%
S7	0.391	5.0%	5.3%
JD1	0.559	12.0%	12.2%
JD2	0.559	10.0%	11.1%

5.2.3 Solids Recovery

In general, when using conventional and JD spigots (with identical underflow diameters, that is, with the same D_u/D_o ratio) with solids introduced into the system, both solids and water recovery were reduced. However, an anomaly occurred while testing spigots JD3 and S3 using the V3 vortex finder (Water Test #17). At a D_u/D_o ratio of 1.19 the solids recovery was 4% higher for the JD spigot; moreover, the liquid recovery was 9% less. A desilter would not operate with such a configuration because the water recovery to the underflow would be too high. Nevertheless, if there were an application, the JD spigot, would, in this case, outperform the conventional spigot by maximizing the solids recovery and minimizing the liquid recovery. Analysis of the data acquired by Davidson et al. (1987), Davis and Tuteja (1990) and the work performed in this study shows that, except for the case mentioned above, the JD spigot always reduces both solids and water recoveries. The results were consistent for both inlet pressures and varying solids concentrations. In all cases, the percentage of solids in the underflow was always higher for the JD spigots.

Getting back to desilter operations, reduced water recovery was a positive sign when using the JD spigots. However, the decreased solids recovery was not. Recall that the main objective of a desilter is to maximize solids recovery (Rs) while minimizing liquid recovery (Rf).

Figures 5-1 to 5-4 illustrate how solids recovery is reduced when using JD spigots (JD1 and JD3) in comparison to conventional spigots (data from Water Tests #3, #7, #11 and #15). The solids recovery obtained by spigot JD2 was quite poor so it was not considered for display on Figures 5-1 to 5-4. The poor performance by JD2 can be explained since recovery of solids and liquids reduces further the distance the JD spigot wedge length protrudes into the conical section of the hydrocyclone. The longer the wedge length (as is the case of spigot JD2), the more of an obstruction the JD spigot becomes. Spigot JD3 had a long wedge length but its large underflow diameter permitted acceptable solids and liquid recoveries. For dewatering purposes these results are encouraging as the objective is to have reduced water recovery to the underflow, even though solids recovery is compromised. The results noted are in accordance with those reported by both Davidson et al. (1987) and Davis and Tuteja (1990) for large diameter hydrocyclones.

For desilting operations, the solids recovery is compromised using the JD spigots when compared to conventional spigots having the same underflow diameter. Additional solids stay in the fluid stream where they accumulate. When solids remain in any mud system, they tend to degrade and reduce in size, making it increasingly difficult for solids control equipment to remove the recirculated solids. It is vital to remove solids efficiently the first time they pass through the

Figure 5-1: Solids and Liquid Recovery From Water Test #3
(Using Vortex Finder V1 and 3% Solids)

Inlet Pressure = 207 kPa

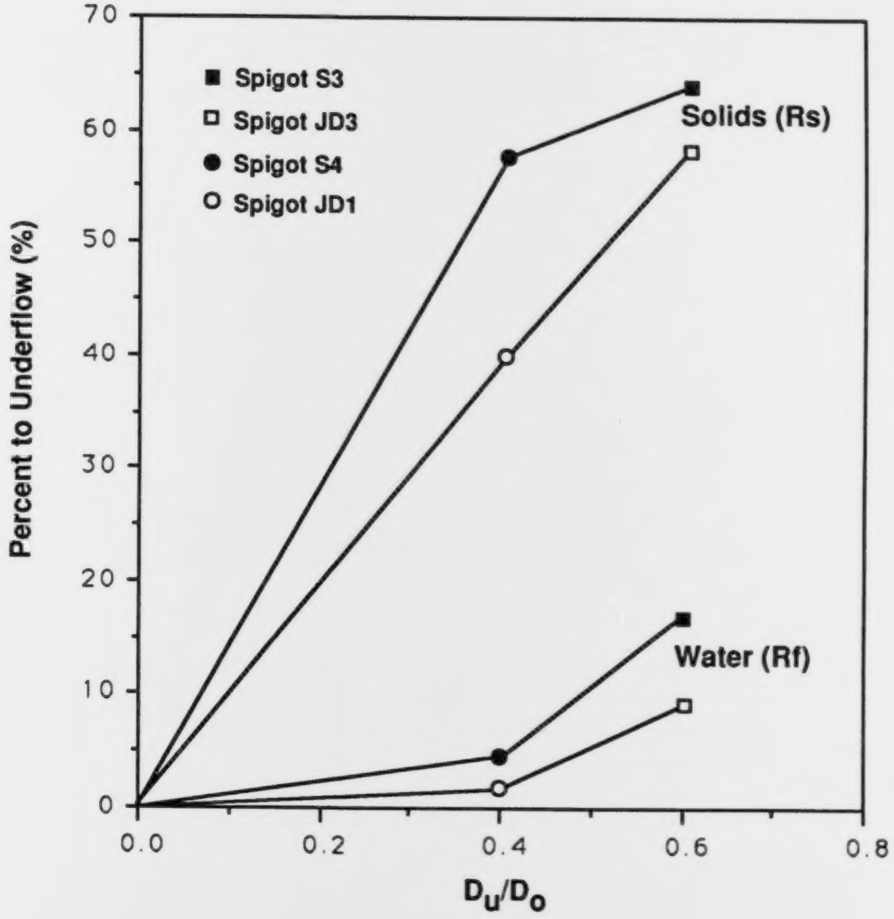


Figure 5-2: Solids and Liquid Recovery From Water Test #7 (Using Vortex Finder V1 and 3% Solids)

Inlet Pressure = 138 kPa

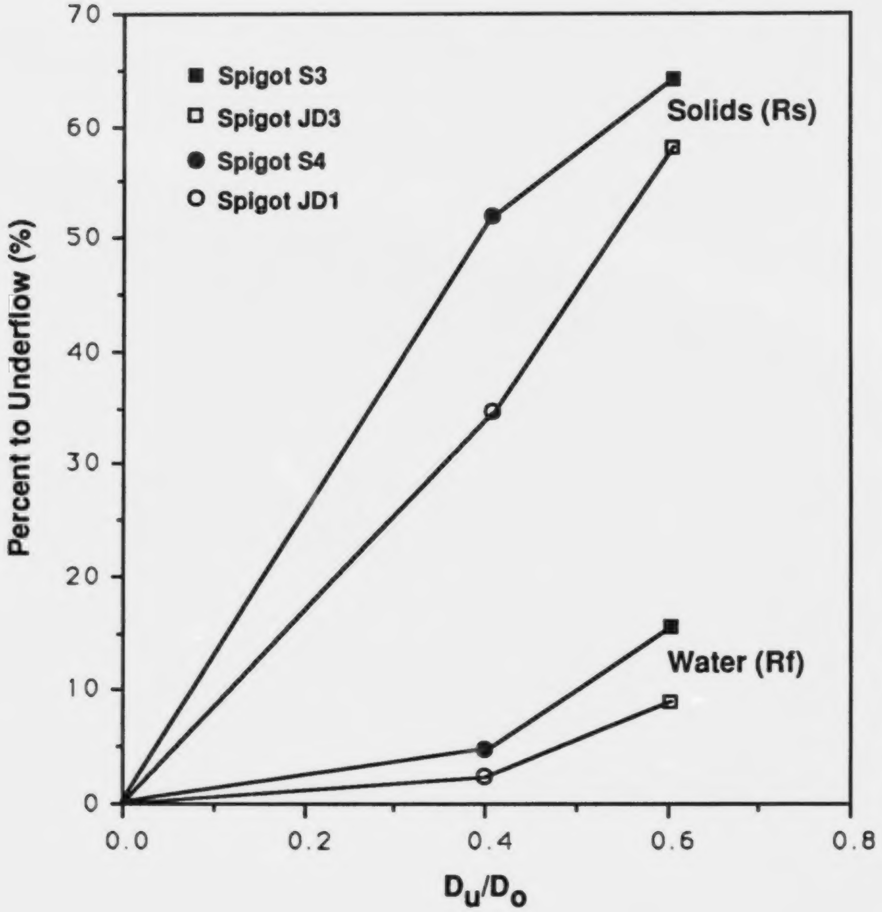


Figure 5-3: Solids and Liquid Recovery From Water Test #11
(Using Vortex Finder V2 and 3% Solids)

Inlet Pressure = 207 kPa

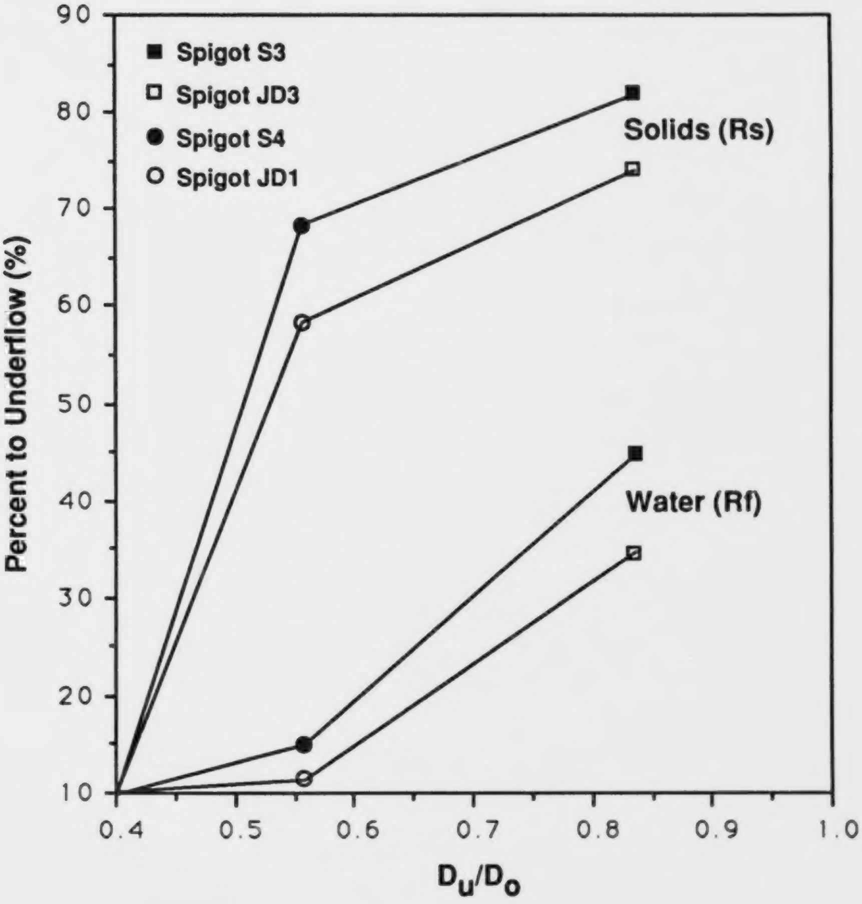
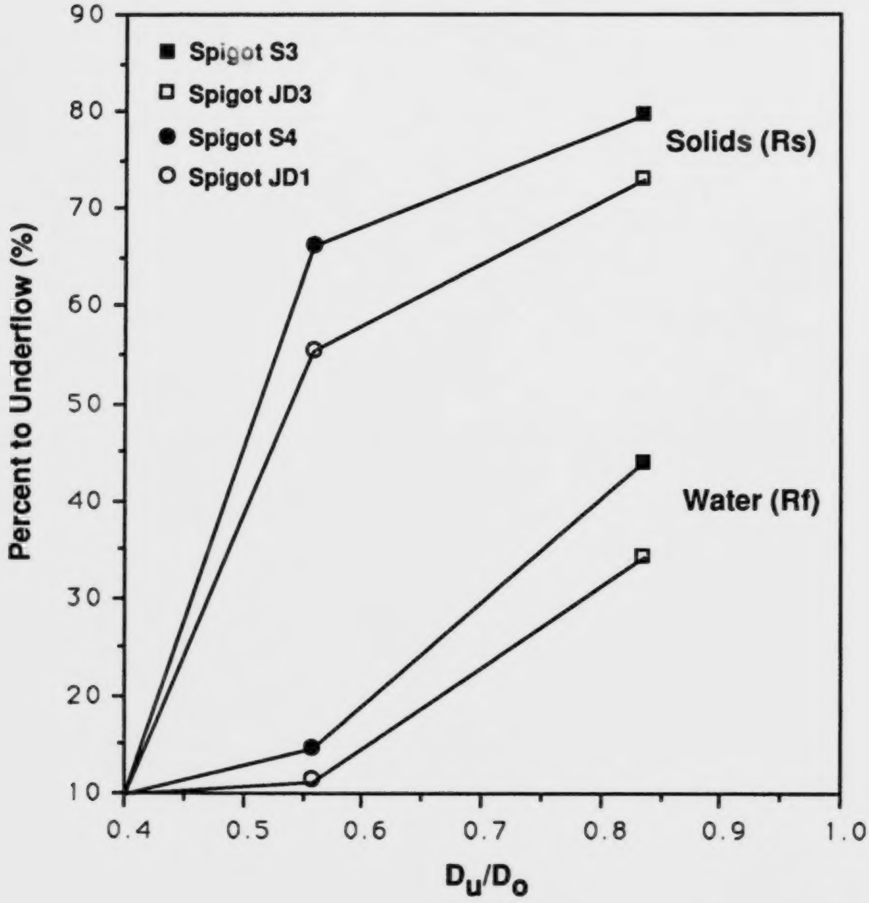


Figure 5-4: Solids and Liquid Recovery From Water Test #15 (Using Vortex Finder V2 and 3% Solids)

Inlet Pressure = 138 kPa



solids control equipment. Once solids are reduced in size below a certain point they cannot be removed efficiently.

Further testing with conventional spigots S5 & S7, and spigots JD1 & JD2, generally exhibited similar results as above. For solids concentrations of 1% and 3%, spigots JD1 and JD2 had lower solids concentrations along with higher water recovery values than did spigots S5 and S7. However, there were some differences. As the solids feed concentration approached 6% by volume, spigot JD1 performed better than spigot S5 when using vortex finder V1. The amount of solids recovery was higher for spigot JD1; the water recovery was lower. This was observed at both inlet pressures, 138 kPa and 207 kPa (Water Tests #4 and #8). Figures 5-5 and 5-6 (using data from Water Tests #4 and #8) illustrate the recovery trend for all the spigots involved. It is important to note that the underflow diameter of spigot JD1 was twice that of spigot S5. The surprising result was not that the solids recovery was superior using spigot JD1 at 6% solids, but that the liquid recovery was also reduced.

The reason for the above result is that the underflow becomes constricted when conventional spigots (with small Du/Do ratios) are exposed to higher solids concentrations in feed slurries. Drilling fluid becomes more viscous as it migrates to the lower apex area of the hydrocyclone and, as a consequence, loses the rotational motion that promotes spray discharge. The apex becomes constricted; thus, solids that

Figure 5-5: Solids and Liquid Recovery From Water Test #4
(Using Vortex Finder V1 and 6% Solids)

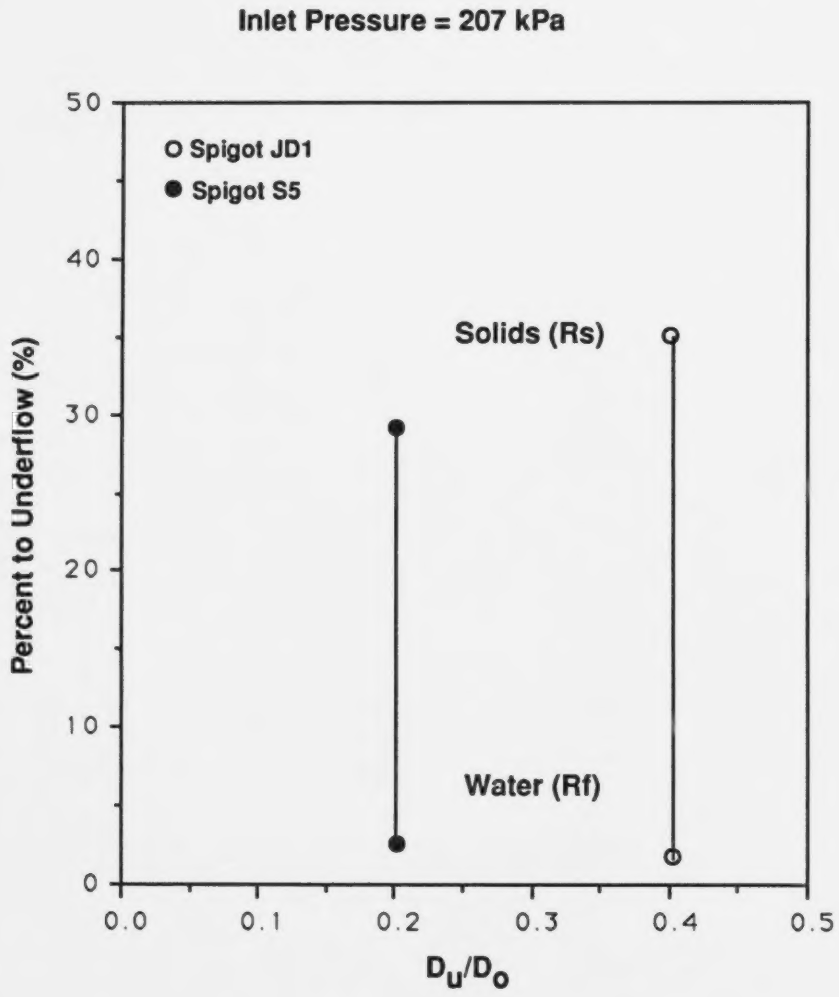
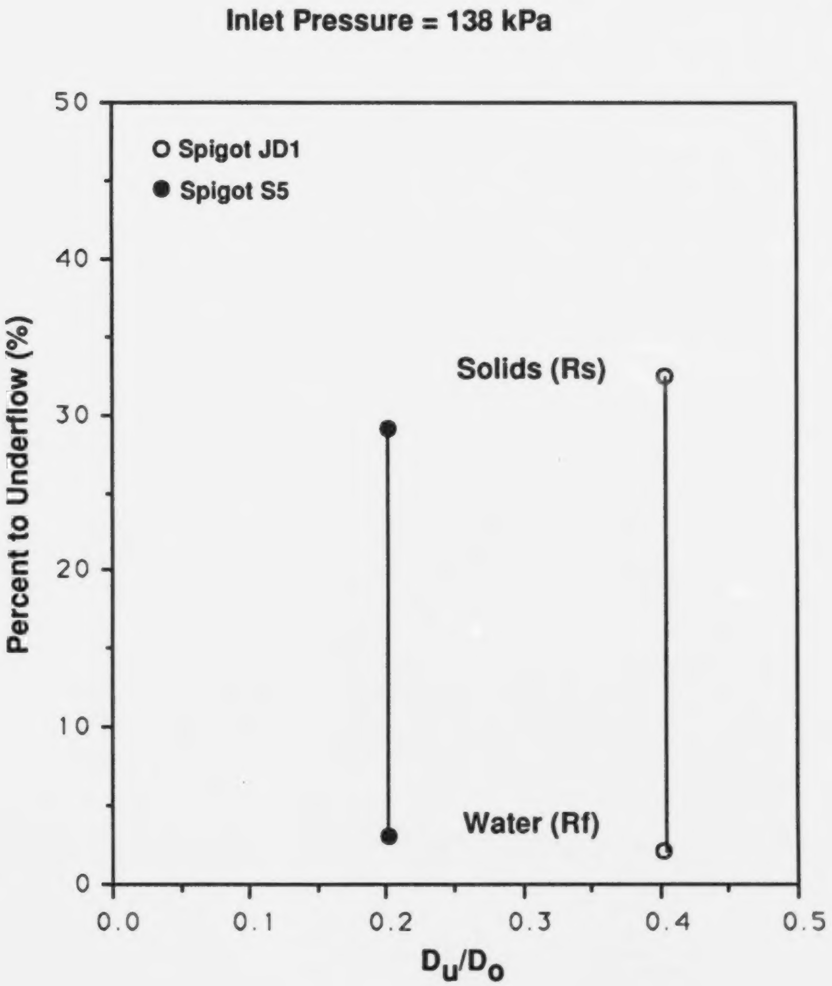


Figure 5-6: Solids and Liquid Recovery From Water Test #8
(Using Vortex Finder V1 and 6% Solids)



would normally go to the underflow bypass to the overflow. Observations made during the experimental runs were that the underflow discharge of the Mozley, using spigots S5 and S7, experienced rope discharge at 6% solids concentration. The JD spigots tested in this investigation never experienced rope discharge during testing with water-only drilling fluids. This was encouraging because rope discharge during desilter operations ultimately leads to a blocked underflow, resulting in no solids removal. As previously mentioned, the underflow percent solids was always higher for JD spigots as compared to conventional spigots (having identical underflow diameters). This was reported by both Davidson et al. (1987) and Davis and Tuteja (1990) for large diameter hydrocyclones. Figures 5-7 and 5-8 (from Tests #4, #7, #12 and #15) illustrate how the underflow percent solids is higher for the JD spigots in comparison to conventional spigots (with equal underflow diameters), with the solids recovery being lower. This was generally the trend for all three vortex finders at all solids concentrations and at both operating pressures.

5.2.4 Corrected Efficiency (Sil_c)

Young (1987) defined corrected efficiency as the drill solids recovery corrected for the liquid and bentonite recovery (see Equation 3-32, Chapter 3). Generally for water-only drilling fluids, the corrected efficiency was superior using conventional spigots as shown in Table 5-5. Recall that

Figure 5-7: Solids Recovery From Water Test #7 and #15
(Using Vortex Finders V1 and V2 3% Solids)

Inlet Pressure = 138 kPa

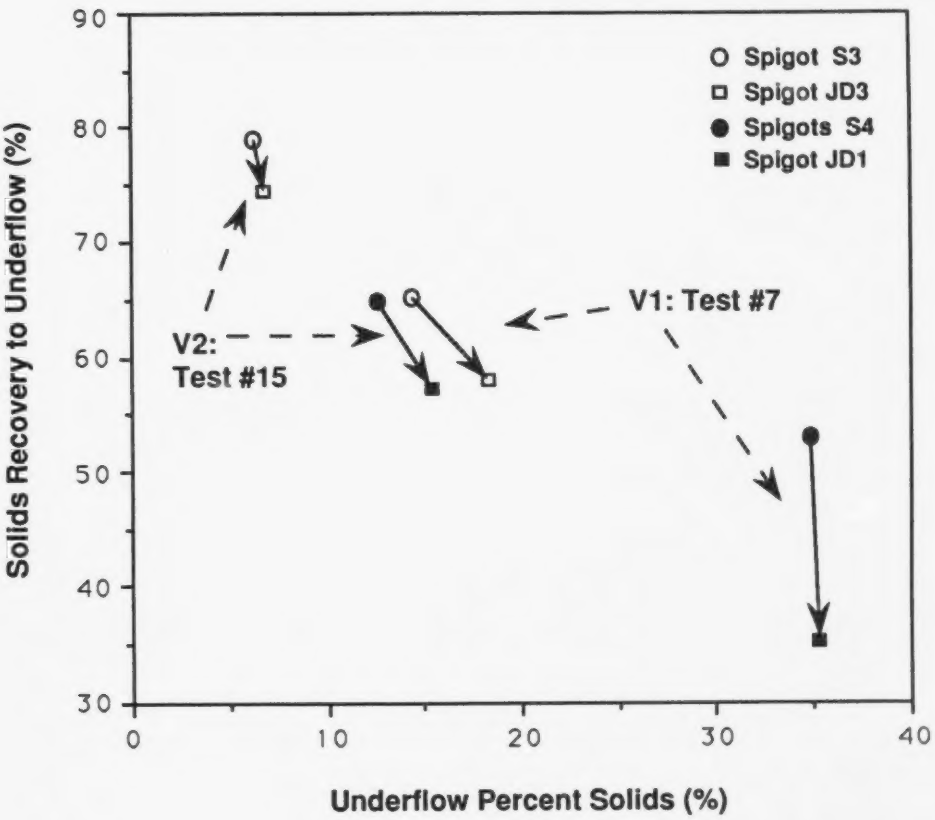
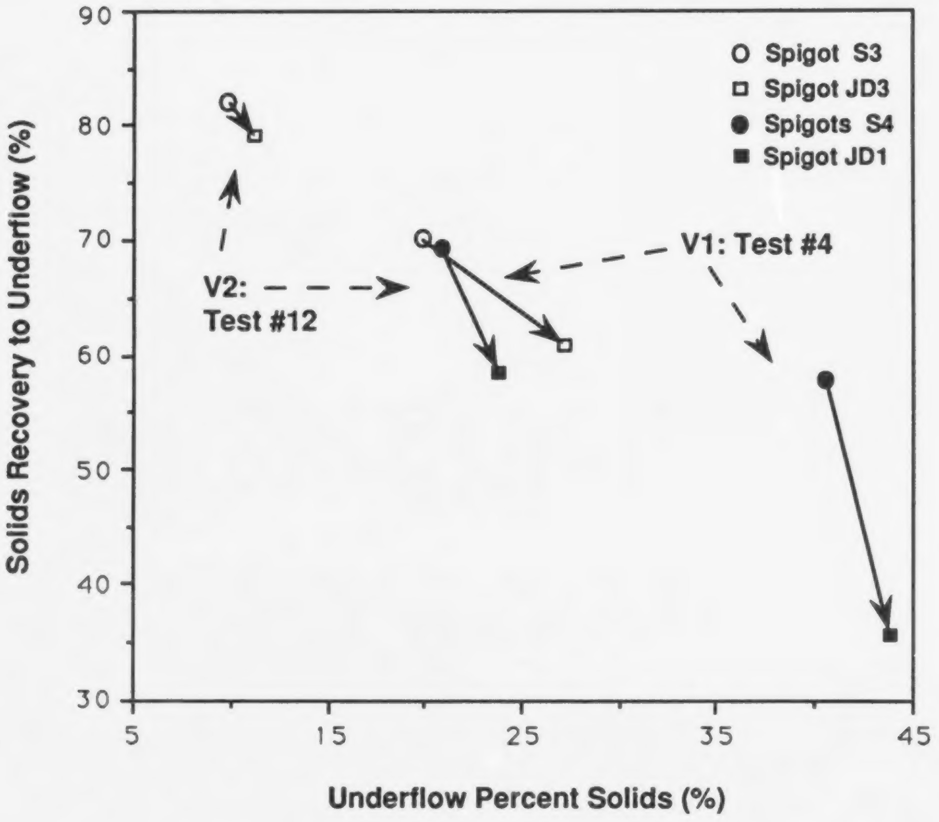


Figure 5-8: Solids Recovery From Water Test #4 and #12
(Using Vortex Finders V1 and V2 6% Solids)

Inlet Pressure = 207 kPa



improved solids recovery was experienced using conventional spigots. This was the primary reason the efficiency was always superior using the conventional spigots. Even though the JD spigots had lower water recovery values, they did not offset the superior solids recovery in Young's (1987) efficiency calculation.

Young (1987) used his efficiency calculation to help optimize the design variables of a desilter. For the purposes of this investigation, the efficiency term is somewhat redundant. For example, if a certain overflow and spigot combination resulted in a solids and liquid recovery of 64% and 14% respectively, the efficiency would be 58%. If another combination was 80% and 25%, the efficiency would be 73%. The second combination has a higher efficiency. However,

Table 5-5
Corrected Efficiencies (Sil_c)(Results from: Water-Only Tests #2,#3, and #4)

Spigot	D_u/D_o	Test #2 1% Solids	Test #3 3% Solids	Test #4 6% Solids
S5	0.202	57.15	43.84	27.21
S7	0.282	61.35	53.53	40.47
S4	0.403	58.95	56.72	55.10
JD1	0.403	48.98	37.97	34.46
JD2	0.403	42.09	33.03	28.75
S3	0.605	64.64	58.14	64.55
JD3	0.605	62.50	54.67	56.15

the liquid recoveries are too high for desilter applications. So, in this instance, the efficiency is of no use.

5.2.5 Flow Split Analysis

The flow split was generally lower for the JD spigots in comparison to conventional spigots. An explanation of this is the lower recovery values (both water and liquid) that result when using JD spigots. The flow split is a useful performance parameter to observe because it is an indication of the volumetric slurry split between the overflow and underflow. If the flow split is quite high in a desilter application, chances are the water recovery values are too high.

Further analysis of the flow split results of this study confirm that an increase in feed solids concentration generally causes the flow split to increase for a desilter using both conventional and JD spigots. Bradley (1965) and Plitt (1976) both illustrated that flow split increases with an increase in solids concentration for conventional spigots. However, this is true up to a point because, as the loading of feed solids increases, conventional spigots start to plug off and compromise recovery to the underflow.

Figures 5-9 and 5-10 illustrate feed solids concentration and flow split to the underflow using JD spigots JD1 and JD3. Spigots JD1 and JD2 generally displayed an increase in flow split as the feed solids concentration increased for all the water tests with the exception of spigot JD3, which seemed to

Figure 5-9: Flow Split Versus Percent Solids to Underflow (From Water Tests #1 Through #4)

$D_u/D_o = 0.403$

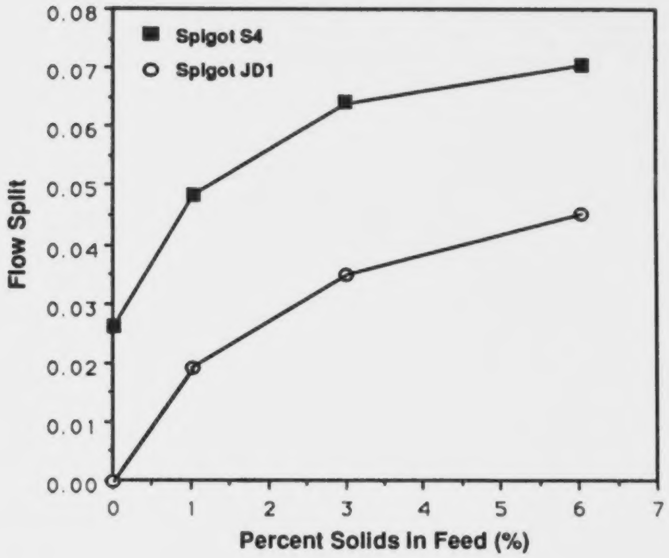
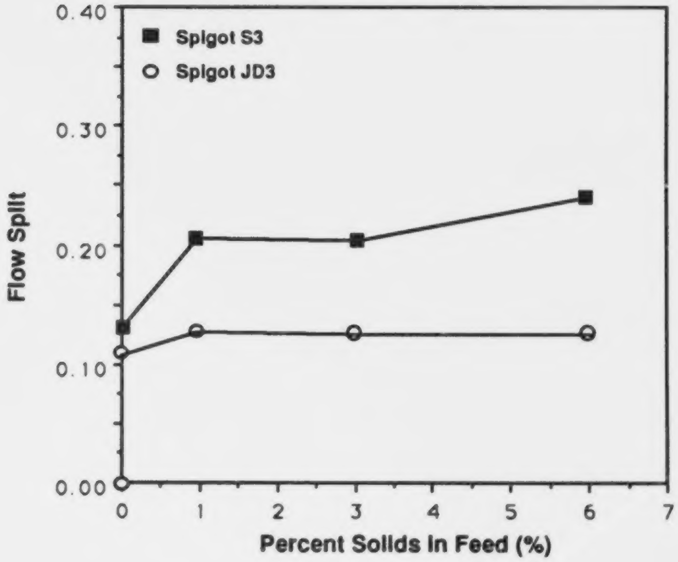


Figure 5-10: Flow Split Versus Percent Solids to Underflow (From Water Tests #1 Through #4)

$D_u/D_o = 0.605$



level out from 3% to 6% solids loading (see Figure 5-10). The flow split results from this investigation are important to desilter applications because they illustrate that JD spigots (JD1 and JD2) behave somewhat like conventional spigots, and therefore can be predicted.

5.2.6 Flow Rate Analysis

For virtually every water test, flow rates through the Mozley decreased slightly when using JD spigots, as illustrated in Table 5-6 (compared to conventional spigots with the same underflow diameter). The decrease in flow rate usually ranged from 0% to 7%. There were some instances where the JD spigots had higher flow rates. However, this can probably be attributed to experimental error. Table 5-6 contains a summary of some flow rate data along with the percentage differences between the JD and conventional

Table 5-6
Flow Rate Data From Water-Only Tests #9 and #10

		Water Test #9		**Water Test #10**	
Spigot	D_u/D_o	**Flow Rate (L/min)**	**% Change**	**Flow Rate (L/min)**	**%Change**
S4	0.403	116.6	-4.54	116.9	-5.56
JD1	0.403	111.3		110.4	
S3	0.605	117.0	-3.67	127.2	-7.46
JD3	0.605	112.7		117.7	

spigots. Davis and Tuteja (1990) reported that for large diameter conventional hydrocyclones, the JD spigots throughput was compromised by 5% to 8%. The reasoning behind this is probably that JD spigots increase the back pressure on the spigot discharge due to the wedged section.

Further analysis of the throughput data reveals that spigot JD1 (D_u = 10mm) generally had higher flow rates than spigots S5 and S7 (D_u = 5mm and 7mm, respectively). The significance of the results concerning flow rate are that JD spigots do not significantly compromise the flow rate through an operating desilter. This means that, in a desilter application, JD spigots can accommodate the drilling fluid flow rate through a solids control system.

5.2.7 Cut Size and Sharpness of Separation

All water-only tests using vortex finders V1 and V2 (at an inlet pressure of 207 kPa) had a particle size analysis performed on the recovered overflow and underflow solids (Water Tests #2, #3, #4, #10, #11 and #12). Forty two partition curves were generated from this analysis with all data reported in Appendix D. Individual partition curves were used to determine the corrected cut size (d_{50c}) and sharpness of separation (m) values. This data was required to evaluate the performance of desilters using JD spigots and for a comparison with conventional spigots. The particle size distribution of specific samples was determined using screens and a Warman Cyclosizer. The size of the distribution (of the particles) ranged from 3.9 to 53.0 microns. This range differed from the standard size analysis reported earlier (Chapter 3) which had a higher end value of 106 microns. Initial sizing showed that most of the particles 53 microns or larger reported to the underflow. Based on this result it was decided to group all of the size ranges above 53 microns into one category.

The use of screens and the cyclosizer for particle size analysis was a very time consuming process. Alternative sizing methods that could have facilitated the sizing procedure were considered. These included the Insitec Laser Probe (PCSV: Particle Counter Sizer Velocimeter) and the Lab-Tech 100 (Particle Size Analyzer). Both units were fully capable of determining particle sizes in the ranges encountered in this investigation. Note that the PCSV measures particles that are carried by gas. For the purpose of this investigation, a flow assembly had to be designed and constructed so that the PCSV could measure particles in a liquid medium. Numerous discussions with the PCSV manufacturer resulted in their engineers indicating that a modified flow assembly for their probe could be constructed.

A modified PCSV design was approved and built to the specifications required for this investigation. Initial testing of the flow assembly indicated no operational problems. Once the flow assembly was fully operational, particles of known size were introduced to the fluid. Problems were encountered immediately when the laser beam could not be focused properly. Technical staff and the manufacturer of the probe could not get the unit to function properly. As a result, no particle sizing could be performed. Further adjustments, including the installation of high quality silica lenses, did not solve the problem.

After the failure of trying to get the Insitec probe to work, the Lab-Tech 100 was tested for use in this investigation. During calibration of the Lab-Tech, a software problem arose with the accompanying computer. Samples with known particle size distributions could not be reproduced using this unit. Attempts were made to get the software problem alleviated. However, the vendor was unable to remedy the problem in a timely manner so screens and the Warmen cyclosizer had to be used for all size analyses. A discussion of the work performed with the PCSV and Lab-Tech 100 is outlined in Appendix B.

As reported earlier, solids recovery to the underflow was less using JD spigots as compared to conventional spigots (with identical underflow diameters). Thus, the cut size (d_{50}) was always larger using JD spigots. This was the case for all the water-only drilling fluid tests.

Cut sizes were determined by plotting the partition curve data. The sharpness of separation (m) was determined from the corrected partition curves by using Equation (3-18) from

Chapter 3. Table 5-7 illustrates partition curve results from Water Tests #2, #3 and #4. Figures 5-11 and 5-12 display the results of four regular partition curves from Water Test #2. Note that for each test the JD spigots had larger cut sizes than the corresponding conventional spigot.

The sharpness of separation was somewhat improved using JD spigots. However, there were specific instances where the conventional spigot had better separation. Davidson et al. (1987) reported that separation improved slightly when using JD spigots on large diameter hydrocyclones. Davis and Tuteja (1990) determined that JD spigots had no effect on sharpness of separation. Results of this study show a slight trend towards the JD spigot improving separation for small diameter hydrocyclones. This is most likely due to the reduction of liquid reporting to the underflow using JD spigots. A reduction in water leads to a reduction in the residual fine particles. This directly improves separation because fines have a higher probability of reporting to the overflow, thereby improving sharpness of separation of the partition curve.

In concluding the water-only drilling fluid testing, it was clear that spigots JD2 and JD3 should no longer be used in the testing. This observation is based upon the results from the previous sections which indicated that only spigot JD1 has any use in desilting operations. In

Figure 5-11: Regular Partition Curves From Water Test #1
(For Spigots JD1 and S4)

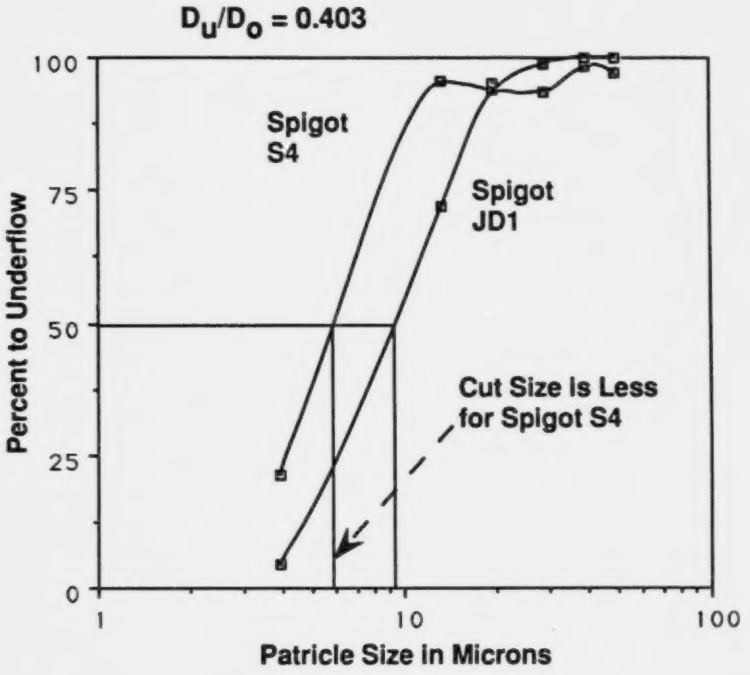


Figure 5-12: Regular Partition Curves From Water Test #1
(For Spigots JD3 and S3)

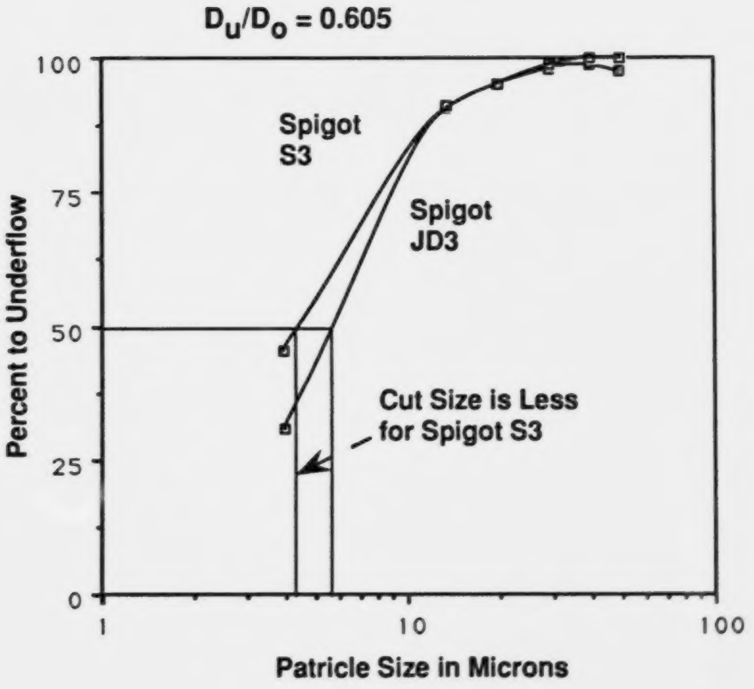


Table 5-7
Water-Only Partition Curve Results

Test	Spigot	D_u/D_o	Percent Solids (%)	D_{50c} (um)	m
#2	S3	0.605	1.0	5.50	1.32
	JD3	0.605	1.0	6.30	1.75
	S4	0.403	1.0	6.15	2.20
	JD1	0.403	1.0	10.30	1.71
	JD2	0.403	1.0	17.00	5.95
#3	S3	0.605	3.0	5.80	1.57
	JD3	0.605	3.0	5.90	1.38
	S4	0.403	3.0	6.85	2.02
	JD1	0.403	3.0	16.70	2.57
	JD2	0.403	3.0	19.00	3.09
#4	S3	0.605	6.0	6.00	1.54
	JD3	0.605	6.0	7.67	1.57
	S4	0.403	6.0	15.20	2.96
	JD1	0.403	6.0	17.50	8.70
	JD2	0.403	6.0	25.00	5.56

addition, recovery and partition curve data from the water-only drilling fluid tests using spigots JD2 and JD3 contributed sufficient data for a complete analysis of these spigots with respect to this investigation.

5.3 Bentonite Drilling Fluids

Eighteen tests were performed using bentonite mud. These tests were considered most important because bentonite is so vital to the drilling industry. No investigation into desilter performance would be complete without considering bentonite drilling fluids.

5.3.1 Solids and Liquid Recovery

The concentration of bentonite was adjusted throughout the testing process. All but two of the experiments were performed at an inlet pressure of 207 kPa. Young (1987) noted that a desilter performed at optimum efficiency with an inlet pressure of approximately 207 kPa. The operating pressure was based on this information.

The first three tests of this section employed a bentonite density of 1050 kg/m^3. Discussions with industry personnel suggested that the density of drilling fluid using bentonite (solid excluded) is usually close to 1050 kg/m^3. In fact it can range from 1020 to 1080 kg/m^3. The concentration of silica drill solids employed ranged from 1% to 6% by volume. The initial three tests were completed to determine how the recovery (Rs and Rf) of spigot JD1 compared with conventional spigots S4, S5, and S7 at different solids concentrations. This test design was followed in the water-only testing so it was used here also. Recall that solids recovery had improved while using spigot JD1 in comparison to spigot S5 at a 6% solids concentration. The first three tests were done to see if the same result would occur while using bentonite drilling fluids.

Results indicate that the bentonite had a considerable negative effect on the solids recovery for all four spigots using vortex finder V1 (in comparison to the water-only drilling fluids). Moreover, as was the case with water-only drilling fluids, the solids recovery was reduced using JD1 spigots (when the underflow diameters were identical). In addition, the liquid recovery was also reduced. This trend was consistent for all three solids concentrations tested. As determined previously, identical results were obtained using water-only drilling fluids.

The solids recovery for spigot S5 was poor. Again, the reason was that the bentonite and drill solids loading was sufficient to cause the underflow to move into rope discharge (due to the small Du/Do ratio). Soon after experiencing rope discharge, the underflow started to plug off. Spigot S7 had solid and liquid recoveries that were almost the same as spigot JD1. However, spigot S7 started to show signs of rope discharge and plugging. Spigot JD1 never displayed any roping tendencies.

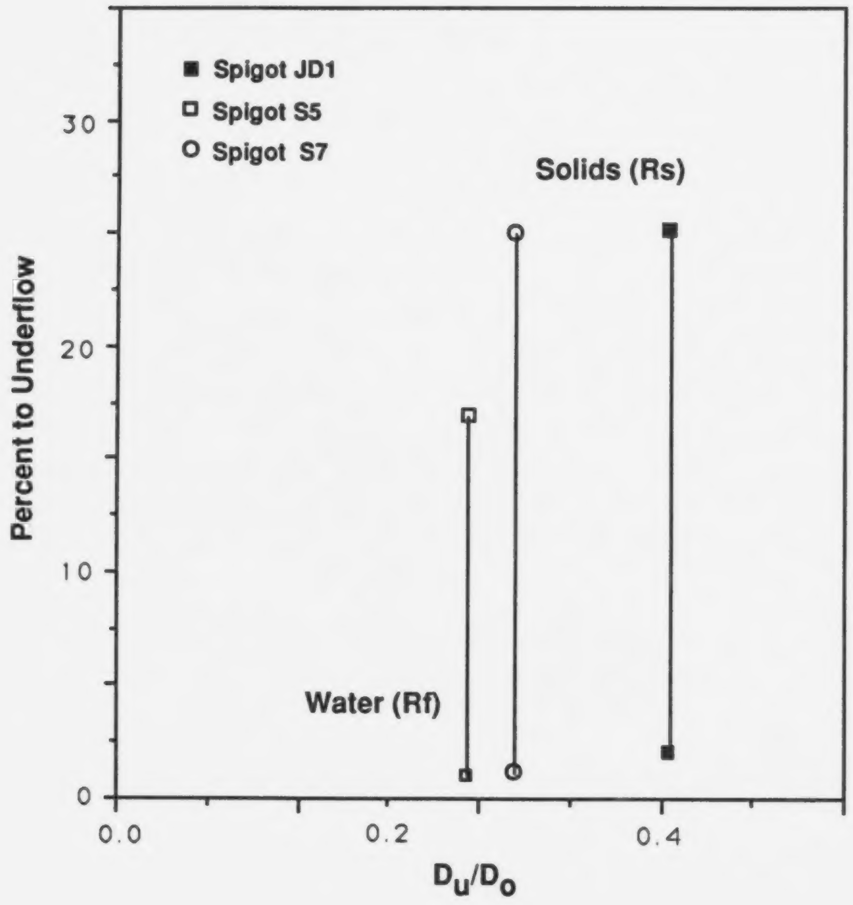
Recall that Bentonite causes the apparent viscosity of a drilling fluid to increase. With increasing apparent viscosity, the drag force F_d on individual particles increases, keeping solids normally destined to the underflow to be carried out the overflow. In addition, the apex of the hydrocyclone becomes constricted when using highly viscous carrying fluids such as bentonite drilling fluids, particularly when the underflow diameter is small (spigot S5 and S7: D_u/D_o of 0.202 and 0.282, respectively). These conditions clearly cause rope discharge and eventual blockage.

Operational difficulties with the test apparatus were encountered throughout the first three tests. These included flow rate surges in the hydrocyclone (due to the high viscosity of the mud) and severe roping for spigots S5 and S7. To ensure proper operation of the experimental apparatus so that sufficient solids recovery could be obtained, bentonite concentrations were reduced. Decreased bentonite levels were based on tests by Young (1987) and discussions with industry personnel. Young used a drilling fluid with a density of approximately 1030 kg/m^3 (excluding bentonite). The same drilling fluid density with bentonite (excluding solids) was subsequently used in this investigation.

The reduced bentonite concentrations significantly improved hydrocyclone operations and increased solids recovery to the underflow. The apparent viscosity of the mud was lower and resulted in the test apparatus having fewer circulating difficulties. Experiments four to seven were performed to obtain modelling data. The drill solids concentration was held at 3% (by volume) resulting in a total mud density of 1085 kg/m^3 (within range of industry levels). Because of the problems experienced with the first three tests, spigot JD1 was re-tested (Mud Test #4) to determine if it could perform better than spigot S5. As illustrated in Figure 5-13, spigot

Figure 5-13: Solids and Liquid Recovery From Mud Test #4
(Using Vortex Finder V1 and 3% Solids)

Inlet Pressure = 207 kPa



JD1 had a higher solids recovery value than did S5. However, the liquid recovery was 1% higher. In addition, the solids recovery and liquid recovery of spigot JD1 were about the same as those of S7. The results from mud test four are encouraging because spigot JD1 has a larger underflow diameter than either spigot S5 or S7, and kept the liquid recovery basically the same or better without compromising the solids recovery. The larger diameter associated with spigot JD1 seems to ensure that it does not move into rope discharge. This is most important for desilter operations because roping and eventual blockage of the underflow comprises solids recovery.

5.3.2 Solids Recovery (Corrected for Bentonite)

Prior to determining the drill solids recovery of a hydrocyclone, a correction is required to account for existing bentonite levels in the drilling fluids. The necessary calculations require some assumptions. Bentonite particles are generally very fine (that is, 2 microns or less) and likely pass through almost any sizing equipment. An assumption was therefore made that the bentonite is not subject to separation when it passes through a hydrocyclone. In other words, for every increment of water passed to either the overflow or underflow, a set amount of bentonite accompanies it.

At the start of each test, the amount of bentonite is known for the total volume of water (based on the mud weight). After samples were collected and dried, each underflow and overflow sample was weighed. The amount of evaporated water minus the set amount of bentonite determines the drill solids weight for a specific sample. Young (1987) also used this assumption. However, he used pure bentonite. Recall that the bentonite used in this investigation had to be corrected for silt content. This was done by adding the silt to the amount of drill solids.

5.3.3 Corrected Efficiency (Sil_c)

The efficiency trends observed for bentonite muds were similar to those observed for the water only drilling fluids. Spigot S4 generally had a higher efficiency than spigot JD1. Conversely, spigot JD1 always had a higher corrected efficiency than Spigot S5. However, the efficiency values were so small, especially those pertaining to the first three tests (high bentonite concentration), that no useful information was obtainable. Basically, a very low efficiency means that the total recovery was poor for a specific operation.

5.3.4 Flow Split Analysis

The flow split was lower for spigot JD1 in comparison to conventional spigot S4 (identical underflow diameter). An explanation of this is the lower recovery values (both water and liquid) that result when using spigot JD1. Recall that this same reasoning applies for water only drilling fluids.

As for the other conventional spigots, S5 and S7, their flow split increased while going from 1% to 3% solids concentration. However, both spigots displayed a small reduction in flow split when they were tested with 6% solids. As explained earlier, the apex of the hydrocyclone becomes constricted when there is a high concentration of drill solids in the mud using spigots S5 and S7. This resulted in spigot JD1 having a higher flow split than both spigot S5 and S7 for the first four mud tests. These results illustrate that all around recovery for desilting operations is somewhat improved when using the JD spigot in comparison to the smaller diameter spigots like S5 and S7.

5.3.5 Flow Rate Analysis

Flow rates (for bentonite drilling fluids) through the Mozley hydrocyclone decreased slightly when using JD spigots as compared to conventional spigots with the same underflow diameter. The reduction was somewhat less than observed for the water-only drilling fluids. However, the trend does substantiate that JD spigots do cause more back pressure in the apex of the hydrocyclone resulting in a reduction of flow rate. Spigot JD1 did have a higher flow rate than spigot S5 for the first three mud tests. Spigot S7 flow rate values hovered close to those observed for spigot JD1.

It is important to note that spigot JD1 did have a higher flow rate than spigot S5. This is due to the restriction at the underflow that results when using small diameter spigots.

5.3.6 Cut Size and Sharpness of Separation

Each bentonite mud test had a particle size analysis performed on the recovered overflow and underflow solids. The most time-consuming portion of this experimental investigation was the particle size analysis of the bentonite drilling muds. A full description of the procedure used is given in Appendix B. Sixty-seven partition curves were generated from the experiments performed, with the resultant partition curve data outlined in Appendix D. Individual partition curves supplied the corrected cut size (d_{50c}) and sharpness of separation (m) values.

The particle size distribution of the bentonite drilling fluids was determined using screens and a Warman cyclosizer. The size range was from 12 to 180 microns. This differed from the standard size analysis reported for water only drilling fluids which had a higher end particle size of 53 microns. As reported in Chapter 3, the bentonite had a 10% silt content. The upper end size range of the silt particles was approximately 180 microns, which explains the results. Because solids recovery was compromised using bentonite drilling fluids, the resultant cut size was higher than water-only drilling fluids under the same operating conditions. As shown by the partition curve, coarse particles did not have a 100% chance of going to the underflow, as was the case with water-only drilling fluids. Thus, to develop the most realistic partition curve, a larger size distribution had to be used for the sizing process.

The cut size was generally larger for spigot JD1 in comparison to spigot S4 (identical underflow diameters) based on results from the first four mud tests. With the exception of Mud Test #2, where the cut size was higher for spigot S4, the trend was consistent for spigot JD1 to have a higher cut size. Again, this is explained by the fact that solids recovery is reduced when using JD spigots in comparison to conventional spigots of identical diameter. Davis and Tuteja (1990) reported that cut sizes were smaller using the JD spigots in some of their tests. However, they noted that this was probably due to experimental error during particle size analysis. The same reasoning can be applied to this study. The trend definitely illustrates that the cut size increases using JD spigots when underflow diameters are identical. Table 5-8 contains partition curve results from Mud Test #4. Two regular partition curves are illustrated in Figure 5-14.

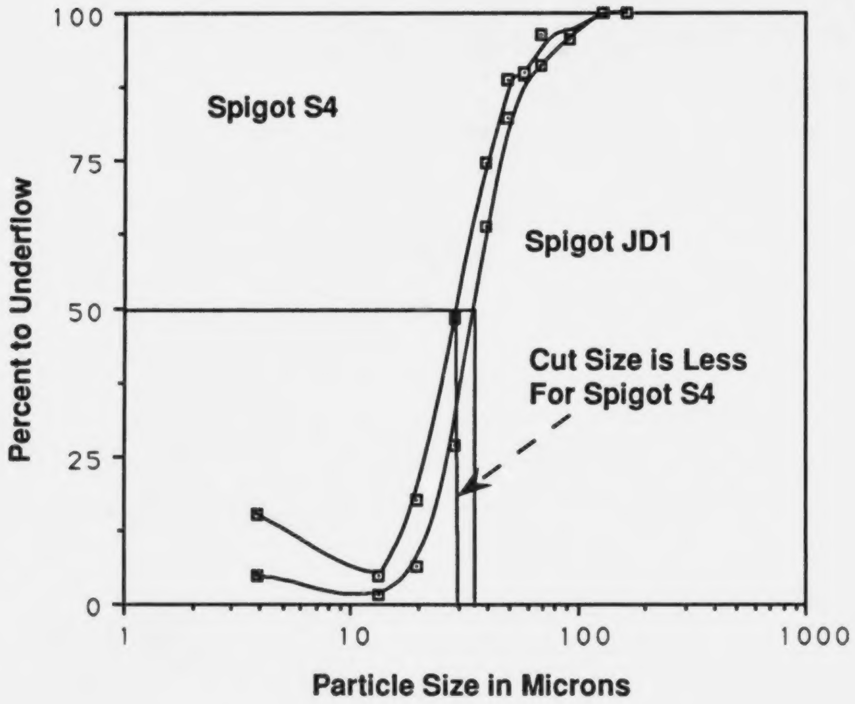
Table 5-8
Bentonite Partition Curve Data
Mud Test #4

Spigot	**D_u/D_o**	**D_{50c} (um)**	**m**
S5	0.202	37.00	4.09
S7	0.282	33.50	3.23
S4	0.403	30.00	2.72
JD1	0.403	34.00	3.39

The sharpness of separation was higher for spigot JD1

Figure 5-14: Regular Partition Curves From Mud Test #4
(For Spigots JD1 and S4)

$D_u/D_o = 0.403$



(Mud Test #4.) However, an obvious trend was not discovered while looking through the partition curve results from the first three mud tests. For example, Mud Test #2 had spigot JD1 having better separation whereas Mud Test #1 had spigot S4 having better separation. Based on these results, conclusive data indicating an improved sharpness of separation for JD spigots (for bentonite drilling fluids) cannot be substantiated.

The JD spigots were not used for any more mud tests after reaching this stage of the experimental investigation. The primary objective of testing JD spigots in comparison to conventional spigots for both water-only and bentonite drilling fluids had been accomplished. The JD spigot had been tested with both high and low density bentonite drilling fluids covering a large range associated with desilter operations.

The final mud tests planned for this investigation were concerned with desilter performance while using bentonite drilling fluids with variable bentonite concentrations. For example, it may be important to understand how solids recovery and cut size are affected with increasing bentonite concentrations in the drilling fluid. This knowledge can indicate at what point cut size drastically increases because of bentonite loading.

5.3.7 Mud Concentration Tests

Mud tests eight through eighteen were known as the mud concentration runs. The objective of performing these experiments was to determine at what concentration of bentonite did the cut size begin to increase. Or, in other words, at what point did the solids recovery become compromised.

All of the concentration mud tests used a 3% drill solids concentration. Spigots S5, S7 and S4 were used along with vortex finder V1. Bentonite concentrations started out at 0.0% and increased by 0.4% for each of the subsequent tests. Practical limitations allowed for only eleven tests. The amount of testing done and the concentration of bentonite adjusted for each test (0.4%) did, however, cover a typical desilter range of usage in industry applications.

The addition of bentonite definitely changes solids recovery and the cut size of desilter operations. The results clearly illustrate that the addition of only 0.4% of bentonite (from Mud Test #8 to #9) caused the solids recovery to go down and the cut size to go up. A summary of all the results from these eleven tests is located in Appendix C. Figures 5-15 and 5-16 illustrate how the solids recovery and cut size changed, respectively, for each addition of bentonite gel (using spigot S7). There is no lower limiting amount of bentonite at which a reduction in solids recovery begins to take place. Both performance parameters are affected once bentonite is added to

Figure 5-15: Amount of Bentonite in the Drilling Fluid versus Drill Solids Recovery (Rs) (Data From Mud Tests #8 to #16)

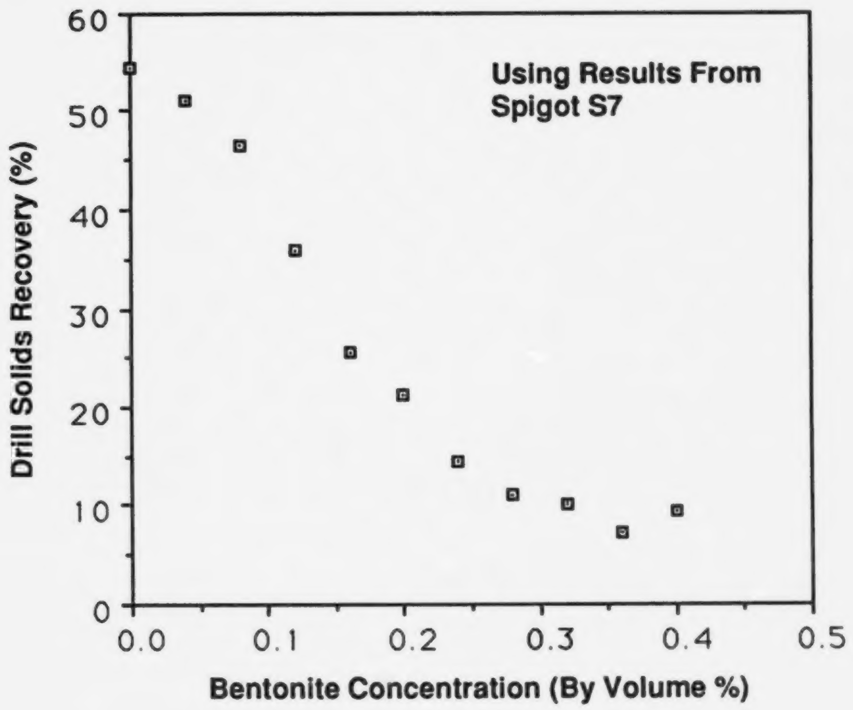
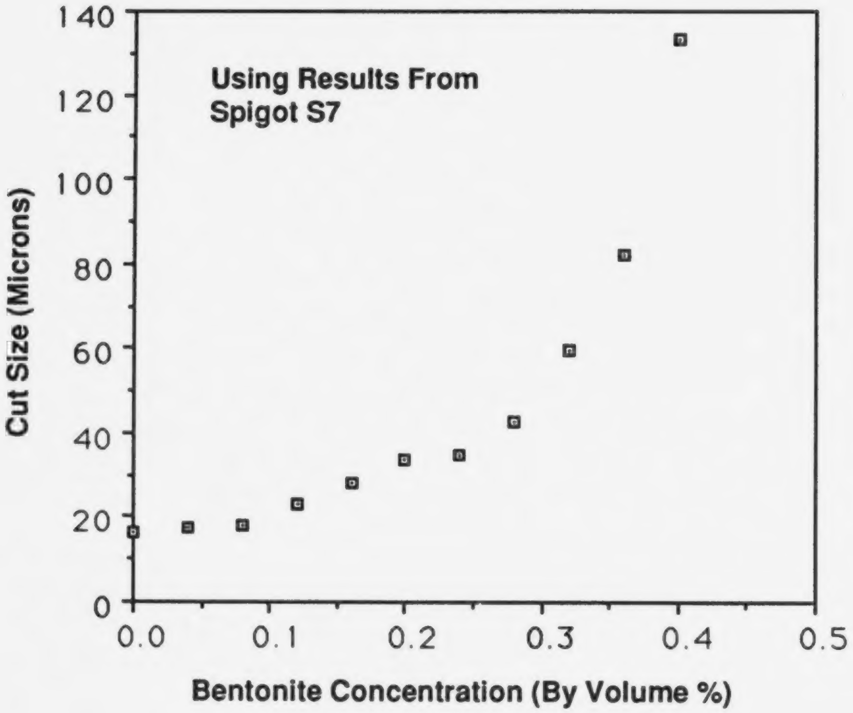


Figure 5-16: Amount of Bentonite in the Drilling Fluid versus Cut Size (d_{50})
(Data From Mud Tests #8 to #16)



the drilling fluid. Mud Tests #16 to #18 were loaded heavily with bentonite. The solids recovery in Mud Test #18 was higher than that shown in Mud Test #17 for all the spigots. This was most likely due to the hydrocyclone experiencing operational problems with such a high loading of bentonite. Spigots S5 and S7 were roping and plugging at this stage giving very low solids recovery results. Based on this, the resulting partition curves were not reliable even though they showed the cut size increasing up until Mud Test #17. For Mud Test #18 the size analysis completely broke down for the bentonite mud at 4.0%. Again, a reliable partition curve could not be generated.

As stated previously, bentonite mud density with no drill solids can go up to 1080 kg/m^3 during industry applications. Based on the results of this investigation, it is unlikely that the desilters would be contributing to any significant solids removal at this density. At high bentonite loadings the viscosity of the drilling fluid becomes too high to allow the hydrocyclone to operate effectively.

CHAPTER VI

DESILTER PERFORMANCE PREDICTION

6.1 Introduction

A data set of experimentally determined hydrocyclone performance parameters was constructed to evaluate the predictive capabilities of the Plitt (1976) and Sharma (1984) empirical mathematical hydrocyclone models. Recall that a description of each model equation is given in Chapter 3. All data used in this section were generated experimentally during the course of this investigation. The purpose of this section is to evaluate how well the two models predicted the performance of desilters using water-only and bentonite drilling fluids. Successful predictions would allow drilling and operating companies the means of evaluating desilter performance under varying operating conditions. A typical varying operating condition is drilling before and after a 1500 m depth where the make-up of the drilling fluid changes from water-only to a bentonite system.

Discussion of the results is divided into two separate sections; the first looks at the Plitt model, the second the Sharma model. JD spigots results are excluded because this analysis considered data generated by conventional hydrocyclone equipment only. The reasoning behind this is that both models investigated in this study were derived using conventional data. The models would require calibration to accommodate the JD spigot data because of the changes JD spigots pose to both the performance and dimensional characteristics of the hydrocylcone. However, the inclusion of JD spigot data for modelling purposes is outlined in Chapter 8 (research recommendations).

6.1.1 The Data Set

As discussed earlier, particle size analysis was not performed on water-only drilling fluid tests using an inlet pressure of 138 kPa. So no cut size or sharpness of separation results were available from these tests. However, all other water-only tests were included in this analysis (Water Tests #2, #3, #4, #10, #11 and #12). Moreover, the bentonite drilling fluid Tests #1 though #7 were evaluated with Tests #8 through #18 being excluded (recall that Mud Tests #8 through #18 were mud concentration runs).

The tests used represented a complete operational range for an operating desilter. With the equipment available for this investigation, all realistic combinations of design and operational parameters were employed. The data that were excluded do not compromise the scope of this investigation. A summary of the calculated and observed results is tabulated in Appendix E.

6.2 The Plitt Model

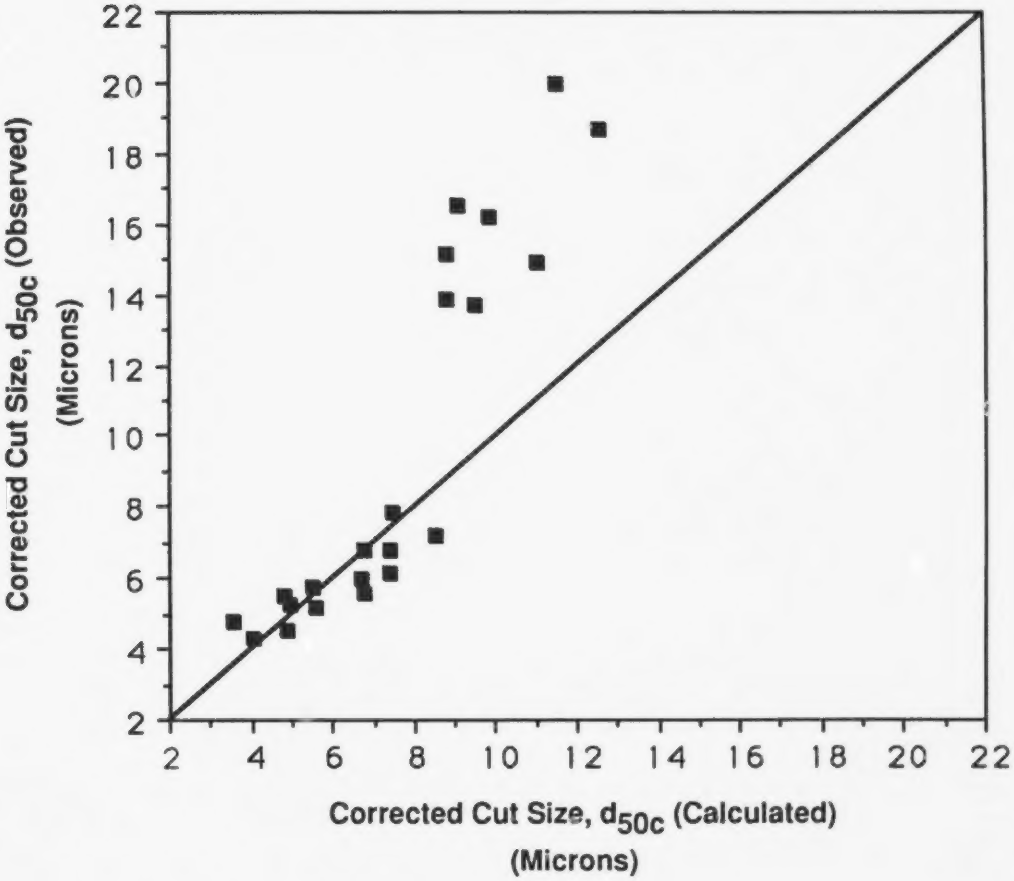
Recall that the four main operating parameters representing the Plitt model were the corrected cut size (d_{50c}), flow split (S), sharpness of separation (m) and pressure drop (P).

The model correlations were not calibrated before being used in this investigation. An objective of this section was to see how well each equation performed without the need of calibration. The correlations were evaluated using a Lotus spreadsheet program. Predicted values were determined and compared to their respective experimental values. A graphical analysis was used to illustrate the calculated versus observed results.

6.2.1 Corrected Cut Size

Corrected cut sizes generated by the water-only runs were generally quite low (less than 20 microns) with the solids recovery to the underflow being higher in comparison to the bentonite drilling fluids. The Plitt correlation predicted water-only corrected cut size results reasonably well in the low size range of less than 10 microns, as illustrated by Figure 6-1. As stated earlier, these cut sizes arose when the solids recovery to the underflow was quite high. This is generally the case for larger D_u/D_o (overflow diameter to underflow diameter D_u/D_o ratio) ratios (equal to or greater than 0.403). As the ratio decreases, the cut size values start to increase for both calculated and observed results (these cut size values were usually greater than 10 microns).

Figure 6-1: Calculated versus Observed Values of Corrected Cut Size For Water-Only Drilling Fluids



The Plitt correlation predicted the increase in cut size with decreasing D_u/D_o ratio; however, the calculated values were usually between 4 to 8 microns less than the observed values. This is due probably to the fact that the Plitt equation is only valid for spray discharge in the underflow. At low D_u/D_o ratios, roping or near-rope conditions increase the d_{50c} due to the crowding effect.

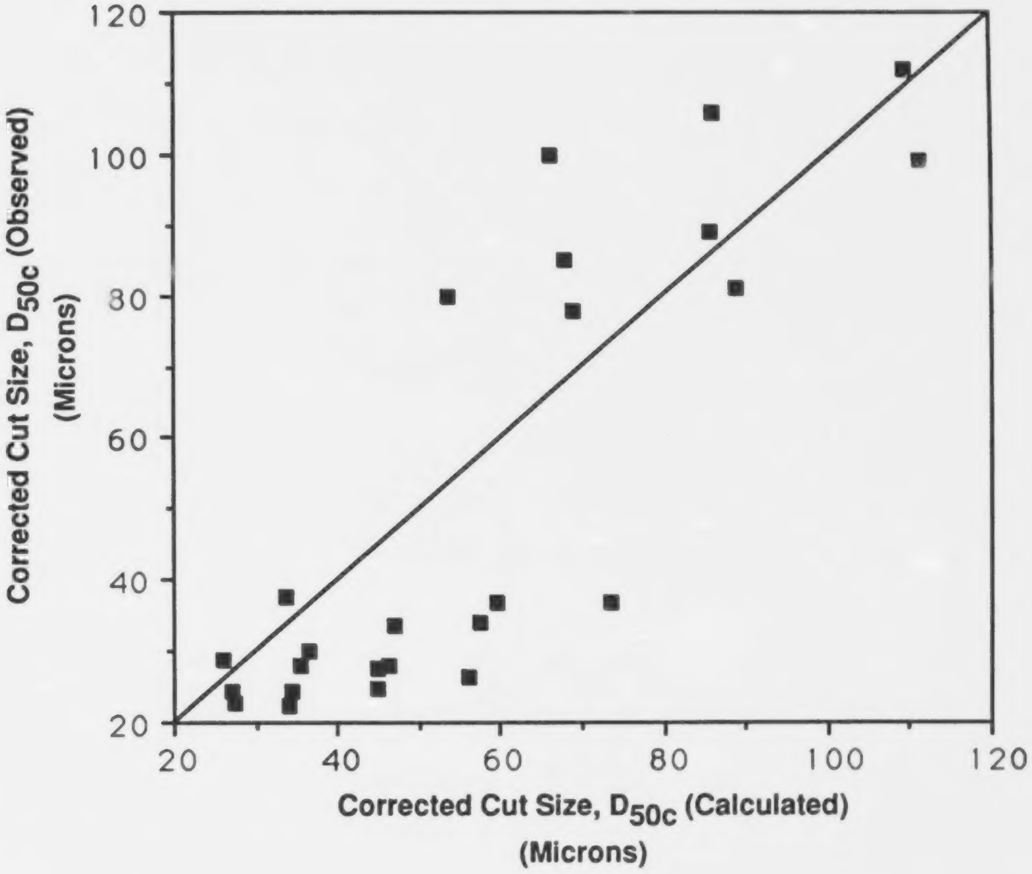
The calculated versus observed corrected cut size results for bentonite drilling fluids is illustrated in Figure 6-2. The correlation and observed values seem very scattered. This can probably be attributed to errors in trying to assess the apparent viscosity when using bentonite. Perhaps the shear rate used in the viscosity measurement is not appropriate considering the fluid is non-Newtonian (see Appendix C).

As stated earlier, in comparison to the water-only sizing analysis, the bentonite muds were much more difficult to size. The scatter in the observed and calculated values can also be attributed to experimental error during the size analysis of the bentonite muds. In any event there does not seem to be any bias in the prediction, i.e. predicting low or high compared to the observed.

6.2.2 Flow Split

Recall that the flow split is the ratio of the underflow volumetric flow rate over the overflow volumetric flow rate associated with a hydrocyclone operation. The results

Figure 6-2: Calculated versus Observed Values of Corrected Cut Size For Bentonite Drilling Fluids



illustrated in Figure 6-3 indicate that the Plitt flow split correlation reasonably predicts the flow split values for water-only drilling fluids. Predictions were best for the flow split values.

The most significant variable affecting flow split is the Du/Do ratio of the operating hydrocyclone. The Plitt model predicted the flow split quite well over a D_u/D_o range of 0.202 to 0.838 (see Figure 6-3) for the water-only drilling fluids. The Plitt correlation is equipped with a D_u/D_o independent variable which works very well when used with water-only drilling fluids.

Figure 6-4 illustrates the calculated versus observed flow split values for the bentonite drilling fluids. The discrepancies between the observed and calculated values are larger for the bentonite drilling fluids. Although some of the predicted values were accurate, in general the predictions were worse than for the water-only drilling fluid. The most likely cause of this can be attributed to some of the operational problems associated with handling the bentonite drilling fluids. In particular, these problems occurred in Mud Tests #1 to #3, which employed a very high concentration of bentonite. In addition, the Plitt flow split correlation does not have a viscosity term associated with it. This most likely causes some of the discrepancies between the observed and predicted flow split values. Nevertheless, the correlation still is somewhat successful at predicting the flow split at

Figure 6-3: Calculated versus Observed Values of Flow Split For Water-Only Drilling Fluids

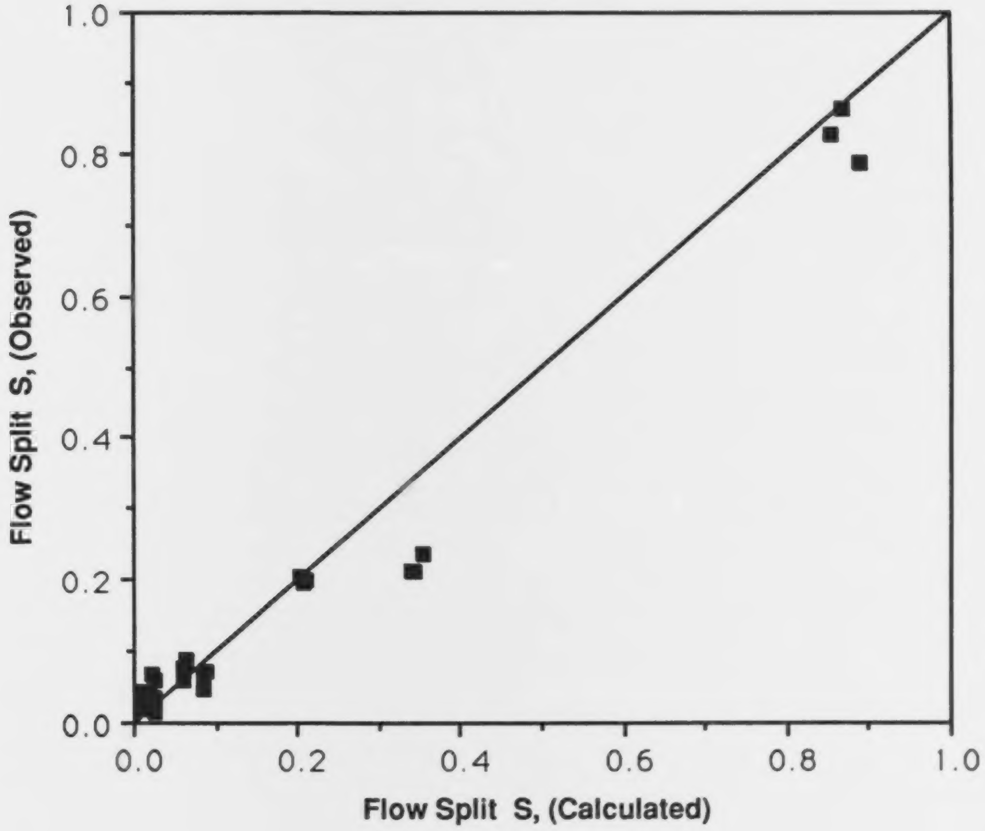
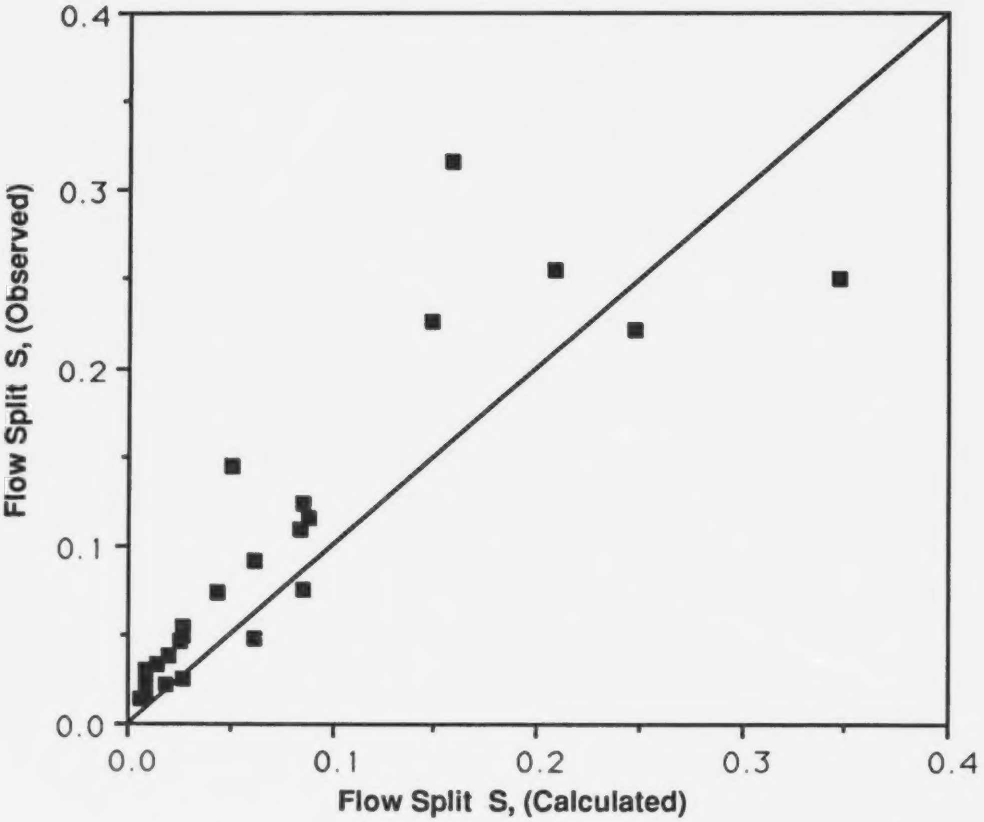


Figure 6-4: Calculated versus Observed Values of Flow Split For Bentonite Drilling Fluids



low values (see Figure 6-4). This is generally the case when the D_u/D_o ratio is low.

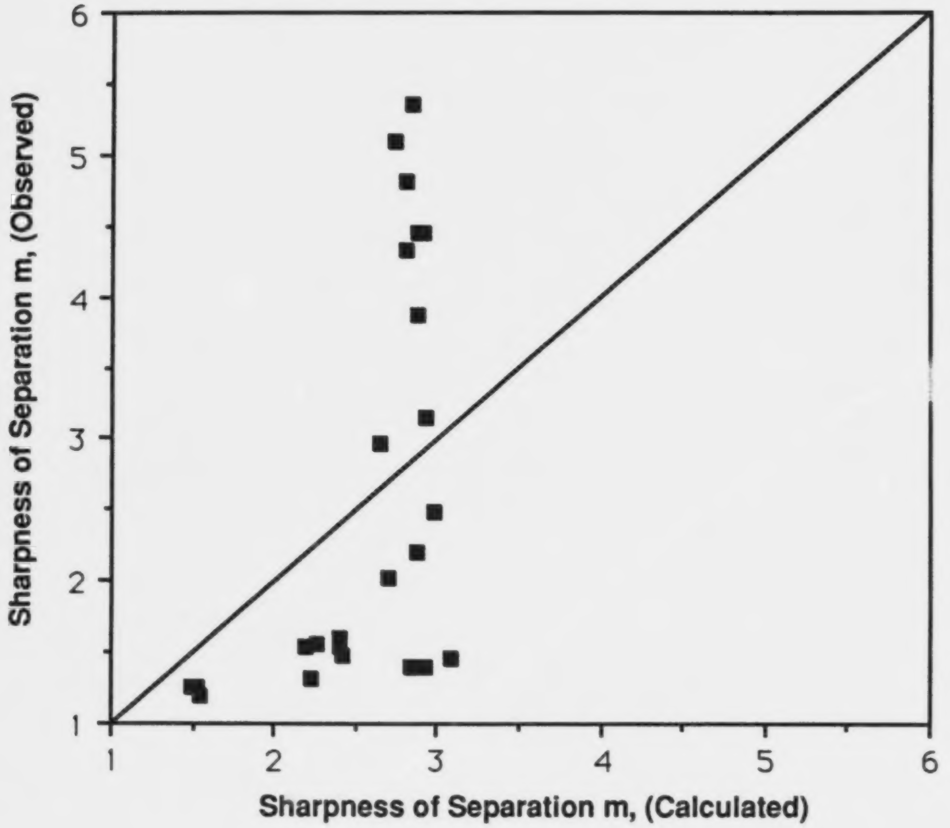
To properly accommodate the viscosity changes associated with bentonite drilling fluids, the Plitt correlation should be calibrated.

6.2.3 Sharpness of Separation

Recall that sharpness of separation is a measure of the classification efficiency pertaining to a partition curve. As illustrated by Figure 6-5, there were significant differences between the observed and predicted values for sharpness of separation. Of the four correlations that make up the Plitt model, sharpness of separation is probably the most sensitive to errors in size analysis. The partition curves generated for the water-only drilling fluids all had the classic "S" shape on the top part of the partition curve. However, the water-only partition curves usually had only one or two points (partition factors) on the lower "S" section. Recall that a partition factor is simply a value depicting the percentage chance a specific size range of particles has of reporting to the underflow. If these values are high, not many particles are reporting to the overflow (the partition curve is not well defined in the small percentage area of the partition curve). This may have caused some errors in the experimentally determined sharpness of separation values.

The major factor affecting the Plitt correlation is the

Figure 6-5: Calculated versus Observed Values of Sharpness of Separation For Water-Only Drilling Fluids

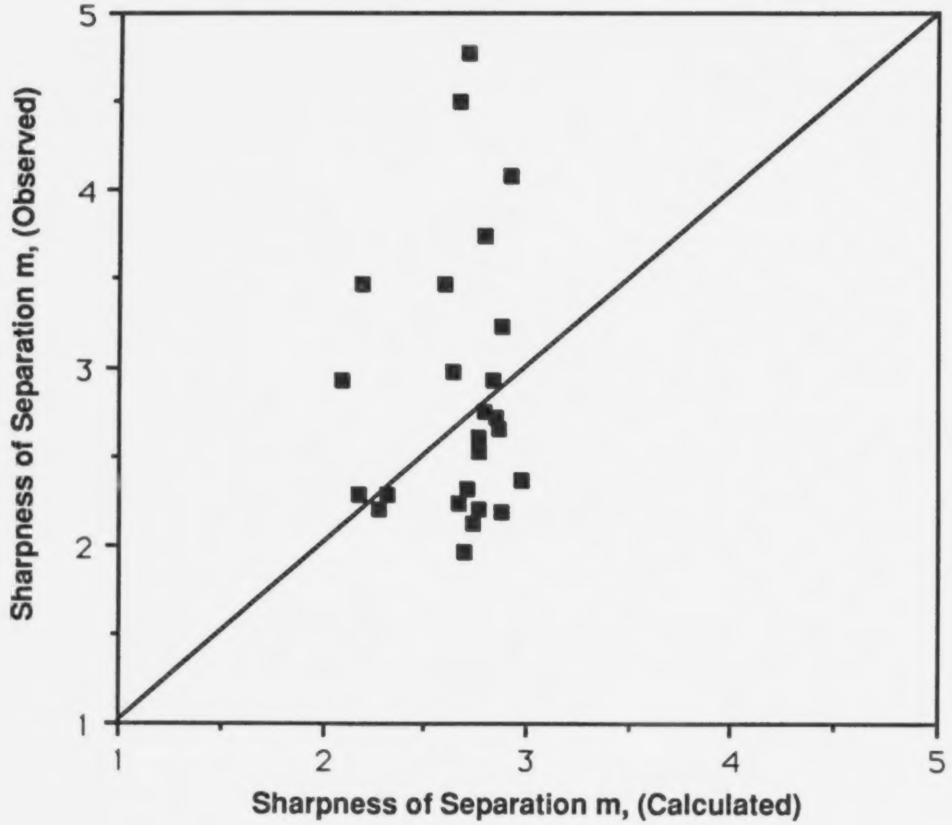


flow split. As stated earlier, the solids recovery to the underflow was generally high for all of the water-only experiments. Recall that the flow split is affected mostly by the D_u/D_o ratio. Both the experimental and correlation techniques of determining the sharpness of separation showed an increase in sharpness of separation as the D_u/D_o ratio decreased. So even though the experimentally determined partition curves had few points on the lower size ranges, the results correctly depicted changes in the D_u/D_o ratio.

Figure 6-6 illustrates the sharpness of separation values for the bentonite drilling fluids. Surprisingly, the Plitt correlation was a bit more successful at predicting separation values for these fluids. However, there were still some large discrepancies when the D_u/D_o ratio was reduced, as shown by the top half of Figure 6-6. Recall that the bentonite adversely affected the solids recovery for a typical desilter operation. However, this did result in better defined partition curves (more points on the lower size range of the partition curve). The resulting experimentally determined sharpness values were probably more representative of the actual separation process. This is probably the reason why the calculated and observed values were somewhat closer for the bentonite drilling fluids at smaller D_u/D_o ratios.

An improvement in the sharpness of separation prediction would definitely occur for water-only drilling fluids if the sizing technique focused on the lower size range. This would

Figure 6-6: Calculated versus Observed Values of Sharpness of Separation For Bentonite Drilling Fluids



improve the definition of the partition curve and the determination of the sharpness of separation. The difference between the predicted and experimental values probably would then be reduced. Note that variation in the value m only has a small effect on the predicted solids split.

6.2.4 Pressure Drop

Figures 6-7 and 6-8 illustrate the Plitt correlation calculations and observed values determined for pressure drop for both water-only and bentonite drilling fluids. In almost all instances, the calculated values for pressure drop were higher than the observed for both drilling fluids. The differences between calculated and observed pressure values were about the same for both drilling fluids. Because the predicted values were usually higher than the observed pressure drop values, the discrepancy could be alleviated partially by calibrating the Plitt correlation. However, the large spread of predicted values in the Plitt correlation does not seem to capture all of the factors affecting the pressure drop for a desilting hydrocyclone.

6.3 Sharma Model

Recall that the four non-dimensional parameters that constituted the Sharma model were the cut size (d_{50}/D_c), sharpness of separation (m), recovery of liquid to the underflow (Rf) and the pressure drop (P_{in}). All the data

Figure 6-7: Calculated versus Observed Values of Pressure Drop For Water-Only Drilling Fluids

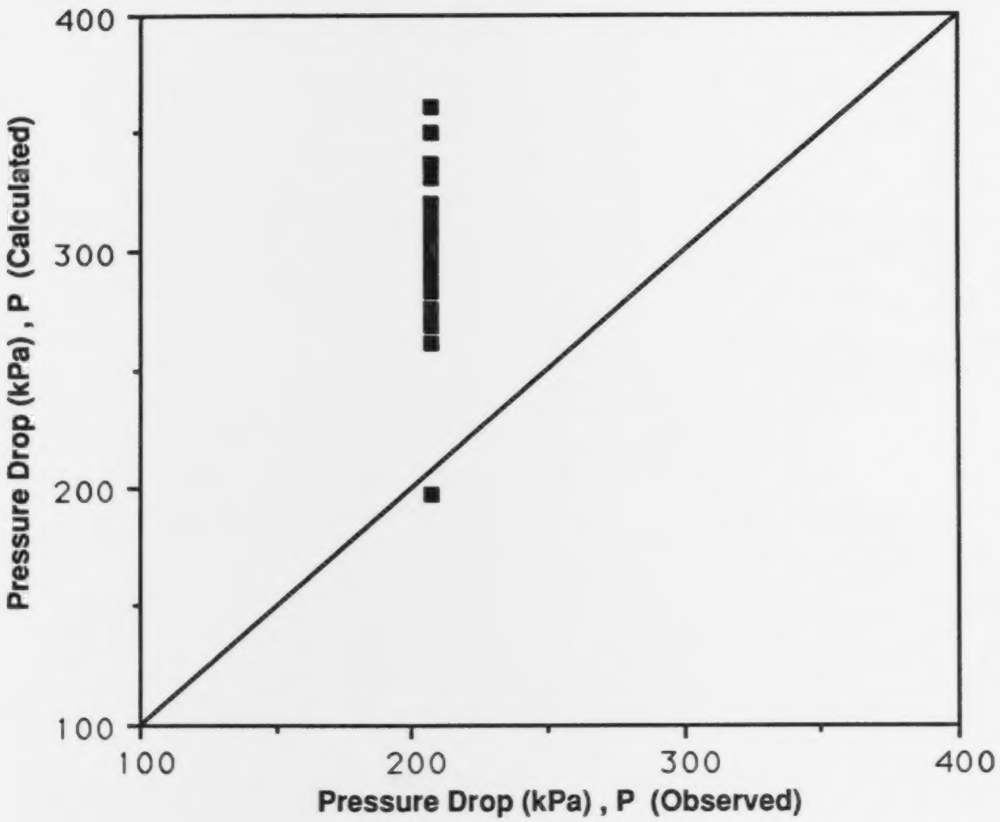
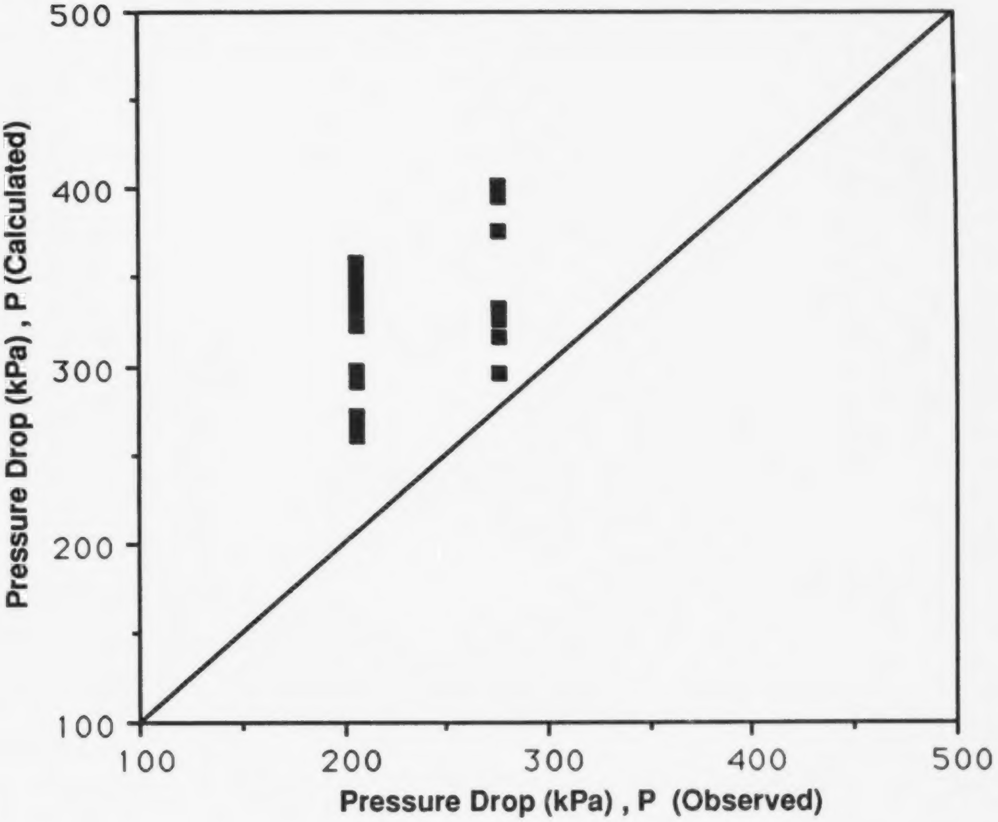


Figure 6-8: Calculated versus Observed Values of Pressure Drop For Bentonite Drilling Fluids



utilized for the Plitt correlation analysis were used with the Sharma model.

Initial results concerning the predictive capabilities of the Sharma model were very poor. To ensure that the investigator had not incorrectly used the equations, another individual loaded the equations with the corresponding operating and design variables. Identical results were obtained. Based on this information, the most likely problem with the equations was the constants in front of the expressions. The equations that make up the Sharma model were very long and complicated. They were generated with a significant amount of statistical analysis; several exponents were involved with each equation. Publication errors in any of the exponents would definitely compromise the predictive capabilities of the correlations.

There was no other investigation in the literature that had tried to validate this model. The model had been developed using drilling fluids so the predicted results should have been reasonably close to the observed results, as was observed using the Plitt model.

To facilitate a correct analysis of the Sharma model, exhaustive attempts were made to contact the author of the model to see if there were any errors in the publication; the attempts were unsuccessful. However, the person who had supervised Sharma while he did this work was successfully contacted (Mr. Leonard Hale). Mr. Hale was familiar with the equations, but he did not know enough about the individual terms and constants to offer any advice on how to improve the analysis.

CHAPTER VII

INDUSTRIAL ASSESSMENT OF JD SPIGOT

The JD spigot did not improve solids recovery to the underflow during side by side testing with conventional spigots of the same diameter. However, it did improve the solids recovery to the underflow while having a lower water recovery when compared to spigot S5 at a solids concentration of 6% by volume. In addition, spigot JD1 had solids recovery values almost equal to spigot S7 during the first four bentonite drilling fluid tests, with slightly higher water recovery values. Furthermore, at no time did spigot JD1 display any plugging tendencies, even when the solids loading was quite high. Recall that both conventional spigots, S5 and S7, displayed some tendency to plug when solids loading approached 6% (by volume) for both water-only and bentonite drilling fluids.

The necessity for better solids control during drilling operations has forced operators to drill wells with the use of centrifuges. Desilters are still used quite extensively in most solids control systems. However, they are more and more being used in conjunction with centrifuges. This practice will not change in the near future. When drilling in areas where the solids loading becomes quite high and using water-only drilling fluids it would be advantageous to use JD spigots instead of conventional spigots. The two main reasons for this are (1) that the JD spigots do not plug and (2) solids recovery is generally not compromised in comparison to the conventional spigots.

Before a precise cost saving could be established for the use of JD Spigots in desilters a more detailed evaluation would have to be carried out. However, if the use of JD spigots could increase the solids recovery by at least 1% - 5% (estimated value based on conventional spigots plugging off periodically), it may not be unreasonable to assume that the drilling rate would increase by up to 1% - 2%. The overall drilling costs associated with the initial 1500 m of a hole could conceivably be reduced by $5000 - $10,000.

CHAPTER VIII

CONCLUSION AND RECOMMENDATIONS

The results of this investigation, for both the experimental and modelling work, bring to light some general conclusions regarding the performance of desilters using water-only and bentonite drilling fluids. These are summarized as follows:

1. Solids recovery of the desilter is sharply reduced when bentonite is added to a drilling fluid system.

2. JD spigots always reduce the water and solids recovery to the underflow of a hydrocyclone (compared to a conventional spigot having an identical D_u/D_o ratio).

3. Using a JD spigot with a D_u/D_o ratio of around 0.403 on a small diameter hydrocyclone results in negligible water recovery to the underflow.

4. At high solids concentrations in the feed, the JD spigot does not display any blocking or roping tendencies in the apex.

5. When compared to some conventional spigots used in desilter applications (spigots with a D_u/D_o ratio of 0.202) the JD spigot improves solids recovery and reduces the water recovery when the concentration of drill solids is high.

6. The sharpness of separation is not compromised when using JD spigots on small diameter hydrocyclones. The shape of their partition curves is similar to those generated by conventional

spigots.

7. For dewatering applications the JD spigot improves the overall performance of a hydrocyclone.

With regards to the two mathematical models evaluated, the following observations can be made:

1. The Plitt correlations for cut size and flow split are reasonable for predicting the experimentally determined cut size and flow split values for water-only drilling fluids.
2. The Plitt correlation is successful at predicting flow split values for bentonite drilling fluids when the observed flow split is less than 0.15. When the flow splits are higher than 0.15, the correlation predictions deteriorate.
3. In its present form the Sharma model is unsuccessful at predicting any of the performance parameters associated with an operating desilter.

Additional research should be directed towards the following areas:

1. Attempt to model the performance of the JD spigot.
2. Evaluate the cost savings which could result from the installation of JD spigots on desilters.
3. Evaluate the possible benefits of the JD spigot on desanders.

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Appendix A

Verification of Mozley Operations Manual

Table A-1

MOZLEY CALIBRATION DATA

WATER TEST WITH NO SOLIDS
INLET PRESSURE = 207 kpa

VORTEX & SPIGOT	SAMPLE U/F (cm3)	VOLUME O/F (cm3)	TEST Rf (%)	MOZLEY Rf (%)	DEV. (%)
NO EXTENSION					
V1/S1	8400.50	7212.50	53.80	56.00	2.20
V1/S2	4045.00	7739.20	34.33	33.00	1.33
V1/S3	1614.70	9341.10	14.74	11.00	3.74
V1/S4	379.60	13283.80	2.78	2.00	0.78
V2/S1	11504.10	1384.70	89.26	91.00	1.74
V2/S2	9812.10	3343.20	74.59	70.00	4.59
V2/S3	7700.06	9776.20	44.06	39.00	5.06
V2/S4	1959.40	12297.60	13.74	12.00	1.74
V3/S1	7746.10	0.00	100.00	100.00	0.00
V3/S2	9359.00	0.00	100.00	100.00	0.00
V3/S3	8456.10	1953.40	81.23	74.00	7.23
V3/S4	6400.10	8607.10	42.65	37.00	5.65
WITH EXTENSION					
V1/S1	8103.30	7190.80	52.98	57.00	4.02
V1/S2	5593.20	12002.30	31.79	35.00	3.21
V1/S3	2068.10	13873.80	12.97	14.00	1.03
V1/S4	343.80	13153.90	2.55	3.00	0.45
V2/S1	12870.10	2119.70	85.86	86.00	0.14
V2/S2	8195.20	4262.90	65.78	66.00	0.22
V2/S3	6333.10	10050.80	38.65	39.00	0.35
V2/S4	1724.30	11097.60	13.45	13.00	0.45
V3/S1	11264.90	0.00	100.00	100.00	0.00
V3/S2	10745.40	413.80	96.29	96.00	0.29
V3/S3	9228.20	3478.10	72.63	71.00	1.63
V3/S4	6151.60	9762.50	38.66	37.00	1.66

Appendix B

Methods of Particle Size Analysis

APPENDIX B

PARTICLE SIZE ANALYSIS

B.1 For Water-Only Drilling Fluids

Size analysis involving the Sil Silica solids began with a predetermined amount of sample (underflow and/or overflow) being washed down a series of wire mesh screens. The screens ranged in size from 106 to 38 microns; specifically, the screens used at this stage were 53, 45 and 38 microns (the reasoning for this was discussed earlier in Chapter 5, Section 5.2.7. The solids were placed in the 53 micron screen; the sample then proceeded though all the screens. The flushing process usually lasted ten minutes.

The screens were then collected and placed in drying ovens for approximately 30 minutes to evaporate the water. Once dried, the solids from each screen were brushed into a holder, weighed, then discarded. Each screen was then cleaned in a sonic bath for 15 minutes. The bath removed particles that lodged in the mesh openings.

Underflow from the 38 micron screen was collected in five gallon pails. The solids were allowed to settle over a twenty four hour period. The water was then decanted off the top; the remaining solids were washed off the pail bottoms with water, then collected in 1000 ml beakers. From there the samples settled for another 24 hours, followed by another decanting procedure. The solids were then collected and run through the

Warman Cyclosizer. The Cyclosizer sized particles from approximately 45 to 11.34 microns. The -11.34 micron amount was determined from a simple mass balance calculation. Table 4-4, in Chapter 3, contains the six particle sizes described here. A description of the Warman Cyclosizer and the operation of this device is outlined in a following section.

B.2 Bentonite Drilling Fluids

The precise amount of drill solids, bentonite, and water were known for each experiment. This helped in determining the bentonite concentration that resulted in each overflow and underflow sample. For a specific amount of water reporting to each orifice, a precise amount of bentonite reports with it. So, as the concentration of bentonite increased for different experiments, the amount of bentonite for each volume of water increases (this was described in Chapter 5 Section 5.3.2). Based on the mud weight at the beginning of the experiment, this value is calculated. As was mentioned in Chapter 4, the bentonite solids do not pass thorough the filtering device which would have facilitated the removal of the water from the sample. This being the case, the samples had to be dried in a large oven. The problem, in doing a proper size analysis on the individual samples after they were dried was getting the caked solids to break apart for the size analysis. When the dried mud samples were first placed in the mesh screens the mud simply clogged together and did not pass through. However, by allowing the sample to hydrate in water for twenty-four hours, the bentonite samples easily passed through the wire screens. This allowed the size analysis procedure to continue. Each overflow and underflow sample was then passed through the screens. As was previously stated, the bentonite mud had a 10% silt content that had larger sized particles accompanying it. So to properly size the bentonite muds, larger sized screens were incorporated into the analysis. The full range is listed in Table 4-4 of Chapter 4.

The same procedure outlined for the water-only muds was used for the bentonite muds. Individual underflow and overflow samples were wet screened for approximately ten minutes with the underflow from the 38 micron screen collecting in five gallon pails. The screens were then collected and placed in drying ovens for approximately 30 minutes to evaporate the water. The solids from each screen were brushed into a holder, weighed and discarded. Then the solids weights were recorded. The screens were then cleaned. The underflow from the 38 micron screen was collected and allowed to settle in five gallon pails. Because of the bentonite, a forty eight hour period was allocated for allowing the drill solids to settle. Water and bentonite were decanted from the five gallon pails and the remaining solids placed in 1000 ml beakers. The beakers were allowed to settle for forty eight hours and then the water was again decanted off the top. The samples were then ready for the Warman Cyclosizer.

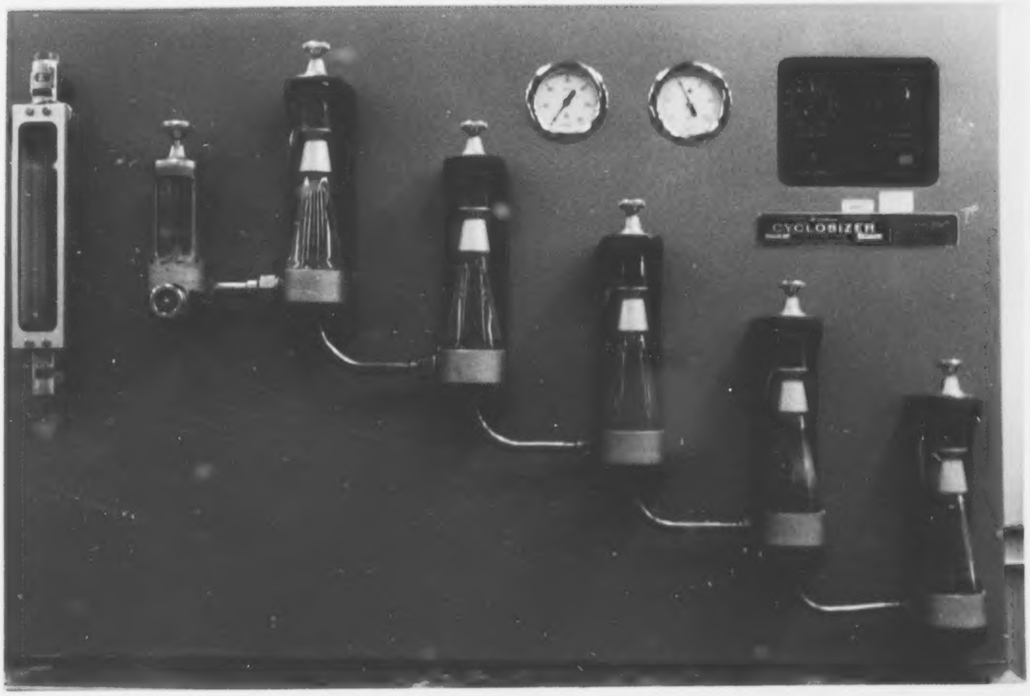
B.3 The Warman Cyclosizer

The Cyclosizer determined the size range from 45 to 11.34 microns. The sizing procedure took place in five hydraulic cyclones wherein fluid rotated under pressure creating centrifugal forces that were much greater than that of the gravitational forces acting upon the individual particles. Each cone separated a specific particle size range. Figure B-1 illustrates the Warman Cyclosizer used for this investigation. Flow patterns created by the rotating fluid were very stable in the cyclosizer and shear forces were also high enough to ensure that flocculation of the fine particles was overcome. The dispersion of all particles in a specific sample size was ensured.

B.3.1 Operation of the Warman Cyclosizer

A specific sample was placed into the sample holder of the Cyclosizer. With the Cyclosizer operating the sample was slowly introduced to the system by adjusting the inlet valve. This procedure took approximately five minutes when the machine operated at the maximum flow rate. Centrifugal forces pushed the solids outwards leaving the coarser solids in each cyclone to flow to the apex of each individual cone. This went on until the last cyclone was reached. A five minute start up period was required to allow the particles time to slowly, and individually, enter the system without clinging together. After the initial five minutes the system was slowed down to

Figure B-1: The Warman Cyclosizer


CYCLOSIZER

a lower flow rate; the rate was maintained for another twenty minutes. After twenty minutes, samples from each cyclone were collected in preweighed 400 ml beakers. The preweighed beakers were then placed in drying ovens until the water had been dried off. The beakers were allowed to cool and then reweighed. The difference in weight was used to estimate the weight of the size fraction for each of the five cones.

With the information from the cyclosizer cones, and the screens, a clean size breakdown was achieved from 180 microns down to 12 microns. From this information a partition curve could be drawn. The Cyclosizer was utilized throughout this study.

B.4 Alternate Methods of Size Analysis

Careful consideration was given to two other, less time consuming, particle sizing techniques before the above procedure was implemented. The techniques involved using a "Portable Laser Probe" and a unit known as the "Lab-Tec 100" (see Figures B-2 and B-3). Both units, when operating properly, supposedly were able to measure particles in the sub micron range and up to at least 2000 microns. A small representative sample of a specific experimental run was introduced into the units for a quick size analysis and report of the results. However, there were some problems with the two units that are worth mentioning. Moreover, considerable time and effort was given to designing a flow assembly for the

Figure B-2: The Insitec Portable Laser Probe

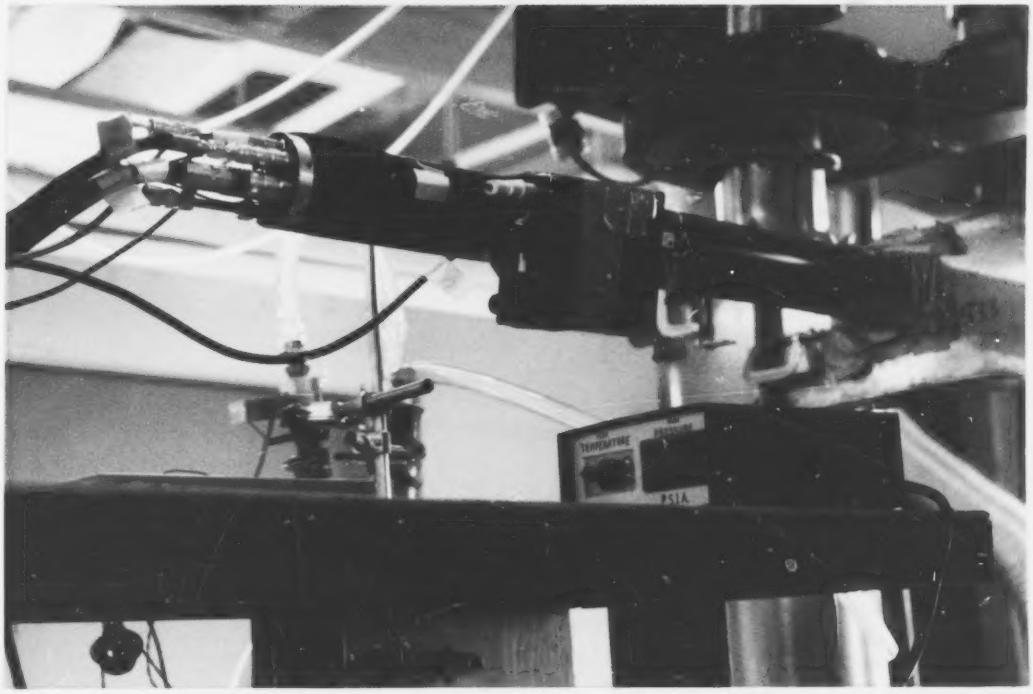
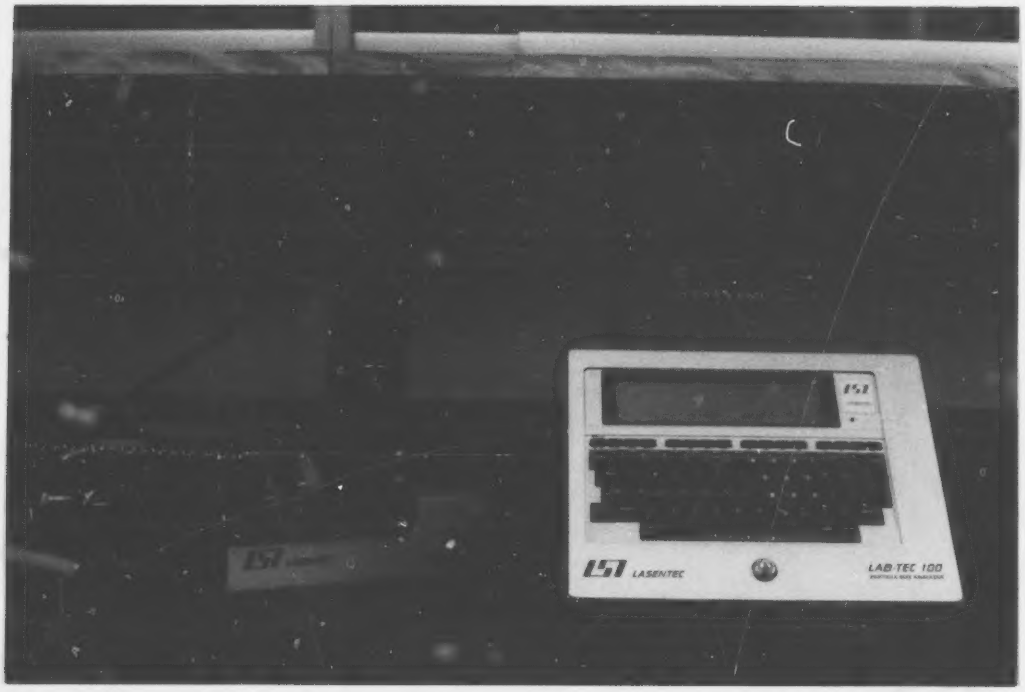

TEMPERATURE
PRESSURE
PSIA

Figure B-3: The Lab-Tec 100 Particle Size Analyzer


LST LASENTEC
LAB-TEC 100

"Portable Laser Probe" to enable the measurement of particles in a liquid phase.

B.4.1 Insitec (PCSV) Laser Probe

The PCSV was a laser based particle size measurement device that provides information such as particle number concentration, size and the frequency distribution of a specific sample that included particles. Particle measurements were made up to 500,000 particles/second (PCSV Operations Manual). The unit came equipped with a laser probe, personal computer (data acquisition system), RS-2 calibration reticle and signal processor. The PCSV was not limited to measuring spherical particles. Particles of varying size, shape and density could be measured with the device. The laser beam was made up of two beams, one small and one large. The large beam measured particles between 1 and 2000 microns, whereas the small beam measured particles from 0.3 to 2.5 microns. This is most useful in sizing drilling fluid containing drill solids because the size range of particles is around 0.1 to 180 microns.

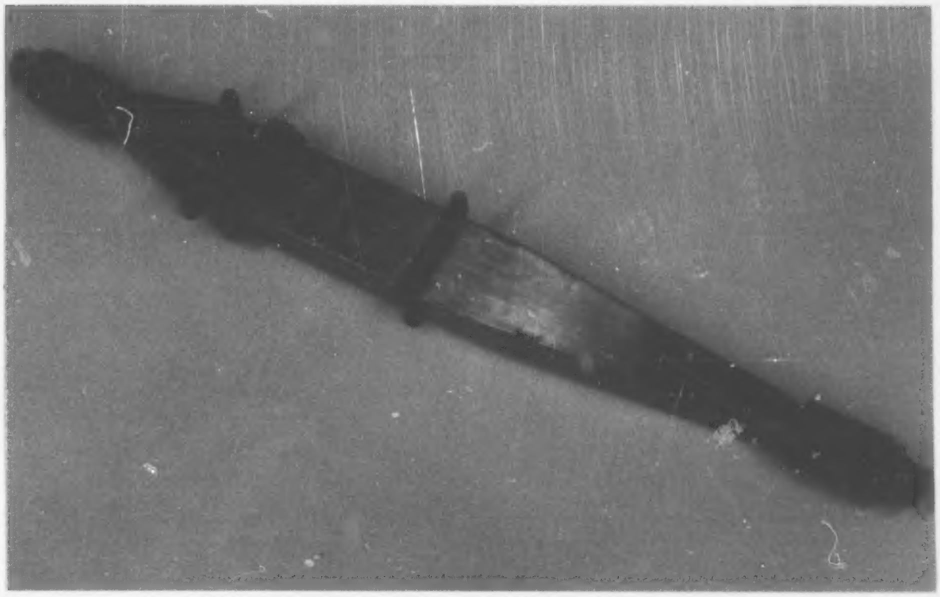
The probe was being used in conjunction with the atomizer on the second floor of the Chemical Engineering building. The unit worked well if particles were carried by air and negligible problems had been reported. For the purposes of this work, and using advice passed on by the PCSV manufacturer

(Insitec), a flow assembly was designed and built for the PCSV. The flow assembly, as shown in Figure B-4, fit in the main chamber of the probe. Distilled water, which was the particle carrying medium, circulated around the flow assembly. Two optical lenses were installed in the assembly so that the laser beam could pass through the it. The water was basically the same as the air, as it carried the differing particles past the laser beam. The information from the flow stream is passed back to the main computer where it is used to undertake the particle size analysis and provide size distribution plots for the different runs generated in this work. The fluid was circulated by a small centrifugal pump. The system, including the lenses and the flow assembly, was closed to air; the system operated without any leaks or operational problems.

B.4.2 Operation Problems With the PCSV

As was mentioned before the circulation system for the probe operated without any operational problems. However, when the probe was initiated, and the two beams were allowed to pass though the fused optical silica lenses, the probe would not align. Proper alignment was necessary to ensure that the small and large beams centered on the sample volume directly between the two lenses. Considerable attention was given to lense selection and only the ones approved by Insitec were used for testing. Alignment ensures that the transmitter and receiver optics are properly aligned for particle measurement.

Figure B-4: The Flow Assembly For the Insitec Portable Laser Probe



Before any readings could be taken the beam had to be aligned and working at close to 100% efficiency. Using only air this was not a problem; however, when the beam was passed thorough water, the unit would not align correctly. Distilled water was used because this supplied a minimum of fine particles in the flowing medium. Considerable time and effort was given to the unit because this would have allowed for more experimental runs because the time consuming size analysis method, mentioned in the first section, would have been avoided.

Insitec was sure that the probe would work as described above. However, reliable data could not be received from the unit when water was the solids carrying medium. If further work were desired with the PCSV, using water as a solids carrying medium, Insitec engineers should come up with a working design first for a flow assembly, so less time is expended using a trial and error method of design.

B.5 The Lab-Tec 100 Particle Size Analyzer

Another method of size analysis considered for this work was the Lab-Tec 100. The Lab-Tec 100, which also uses a laser beam, directs a beam into a magnetically stirred beaker (that holds solids emersed in water). The beam is reflected back from the surface of the particles. This light is detected and the time it takes to get back to the microprocessor contained in the Lab-Tec is measured. The time it takes for this to happen relates to the size of the particle. The time, which is known as the transit time, is then directed into one of eight channels. Each channel gives a characteristic average size for a particle.

A sample is placed in the unit and the beam is directed into the sample. The particles are hit with the beam and from this a distribution of the particles according to size and distribution is given. A computer processes this data and a plot of the analysis is generated.

The Lab-Tec 100 worked a lot better than the PCSV laser probe. However, when a sample of drilling fluid including bentonite was place in the Lab Tech, differing size breakdowns were given each time the unit was used. If four measurements were made with the Lab-Tec 100, four different distributions were generated. This is satisfactory if the data required is for just a reliable breakdown of the solids. However, for plotting partition curves where a precise measurement is required for differing size ranges, the Lab-Tec performance was considered to be unsatisfactory. There were problems with the basic software of the unit and communications with the vendor of the software were resulting in no progress.

The different problems associated with the above two particle size measuring devices resulted in screens and the cyclosizer being chosen for the measuring devices for this study. The screens and Cyclosizer method was labour intensive and time consuming; however, the results were believable and reproducible.

Appendix C

Water-Only and Bentonite Solids and Liquid Recovery Data

TABLE C-1 WATER-ONLY DRILLING FLUID RECOVERY RESULTS

WATER TEST #1

=============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1000.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 0.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S
1	V1/S5	0.202	158.4	0.0	0.40	0.00	0.004
2	V1/S7	0.282	144.6	0.0	0.90	0.00	0.010
3	V1/S4	0.403	168.7	0.0	3.00	0.00	0.026
4	V1/JD1	0.403	160.7	0.0	0.00	0.00	0.000
5	V1/JD2	0.403	162.5	0.0	0.00	0.00	0.000
6	V1/S3	0.605	164.9	0.0	13.00	0.00	0.130
7	V1/JD3	0.605	177.8	0.0	12.00	0.00	0.116

WATER TEST #2

=============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1020.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 1.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	158.5	25.57	1.64	57.84	0.022	57.14
2	V1/S7	0.282	154.8	37.02	1.10	61.77	0.018	61.35
3	V1/S4	0.403	127.5	18.31	3.89	60.54	0.049	58.94
4	V1/JD1	0.403	171.5	35.75	1.22	49.60	0.019	48.98
5	V1/JD2	0.403	173.6	33.47	1.16	42.76	0.017	42.09
6	V1/S3	0.605	178.3	5.52	16.90	70.62	0.214	64.64
7	V1/JD3	0.605	143.2	7.98	11.03	66.64	0.134	62.05

WATER TEST #3

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1048.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	156.2	44.54	1.60	44.74	0.029	43.84
2	V1/S7	0.282	158.9	43.88	2.02	54.47	0.036	53.53
3	V1/S4	0.403	170.9	31.58	4.33	58.60	0.065	56.72
4	V1/JD1	0.403	172.9	35.29	2.28	39.38	0.035	37.97
5	V1/JD2	0.403	175.7	39.37	1.63	34.13	0.027	33.04
6	V1/S3	0.605	170.5	10.87	16.06	64.87	0.210	58.14
7	V1/JD3	0.605	163.2	16.25	9.47	58.97	0.120	54.67

WATER TEST #4

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1085.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 6.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	164.0	37.61	2.65	29.17	0.043	27.21
2	V1/S7	0.282	161.7	43.12	3.41	42.50	0.060	40.47
3	V1/S4	0.403	176.2	40.67	4.23	57.00	0.073	55.10
4	V1/JD1	0.403	175.2	44.12	2.59	36.16	0.046	34.46
5	V1/JD2	0.403	192.2	40.02	2.54	30.56	0.042	28.75
6	V1/S3	0.605	171.5	20.72	16.11	70.26	0.237	64.55
7	V1/JD3	0.605	166.5	27.20	9.06	60.12	0.133	56.15

WATER TEST #5

=============

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1000.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 0.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S
1	V1/S5	0.202	131.6	0.0	1.00	0.00	0.006
2	V1/S7	0.282	131.4	0.0	1.40	0.00	0.006
3	V1/S4	0.403	136.3	0.0	5.00	0.00	0.003
4	V1/JD1	0.403	129.3	0.0	0.30	0.00	0.048
5	V1/JD2	0.403	131.3	0.0	0.00	0.00	0.000
6	V1/S3	0.605	138.2	0.0	18.00	0.00	0.213
7	V1/JD3	0.605	133.4	0.0	12.00	0.00	0.142

WATER TEST #6

=============

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1020.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 1.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	133.9	22.41	1.83	55.27	0.024	54.43
2	V1/S7	0.282	129.4	26.45	1.49	56.26	0.020	55.60
3	V1/S4	0.403	133.6	18.14	3.53	57.48	0.044	55.92
4	V1/JD1	0.403	136.3	31.55	1.33	45.86	0.020	45.13
5	V1/JD2	0.403	146.3	32.44	0.99	36.59	0.015	35.96
6	V1/S3	0.605	135.8	5.15	17.30	67.02	0.219	60.12
7	V1/JD3	0.605	140.9	6.72	11.30	61.18	0.136	56.23

```
WATER TEST #7
=============
FEED PRESSURE = 138 kPa        MUD WEIGHT: =   1000.00 kg/m3  W/O SOLIDS
WITH EXTENSION                                 1048.00 kg/m3  W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY =   0.5 (cp)

CUT   VORTEX/  Du/Do  FEED (Q)   SOLIDS    Rf     Rs       S      CORR.
      SPIGOT          FLOW RATE   U/F     (%)    (%)              EFF.
                       (L/min)    (%)                              (%)
===================================================================
  1    V1/S5   0.202     136.2    33.11    1.95  40.00  0.029  38.80
  2    V1/S7   0.282     129.6    34.38    2.23  47.53  0.034  46.33
  3    V1/S4   0.403     145.5    35.53    3.88  53.90  0.061  52.04
  4    V1/JD1  0.403     147.7    35.87    2.37  34.39  0.037  32.80
  5    V1/JD2  0.403     149.7    34.87    1.99  28.21  0.030  26.75
  6    V1/S3   0.605     143.3    14.66   16.12  66.26  0.221  59.78
  7    V1/JD3  0.605     135.6    18.93    9.66  58.43  0.130  53.98
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WATER TEST #8
=============
FEED PRESSURE = 138 kPa        MUD WEIGHT: =   1000.00 kg/m3  W/O SOLIDS
WITH EXTENSION                                 1090.00 kg/m3  W/SOLIDS

FEED SOLIDS CONCENTRATION = 6.0%
VISCOSITY =   0.5 (cp)

CUT   VORTEX/  Du/Do  FEED (Q)   SOLIDS    Rf     Rs       S      CORR.
      SPIGOT          FLOW RATE   U/F     (%)    (%)              EFF.
                       (L/min)    (%)                              (%)
===================================================================
  1    V1/S5   0.202     137.1    30.12    3.82  30.01  0.055  27.24
  2    V1/S7   0.282     127.9    39.05    3.75  40.86  0.062  38.55
  3    V1/S4   0.403     134.9    42.18    4.18  51.96  0.073  49.87
  4    V1/JD1  0.403     140.1    39.87    2.89  32.83  0.048  30.83
  5    V1/JD2  0.403     142.9    39.69    2.47  27.77  0.040  25.94
  6    V1/S3   0.605     135.3    20.93   14.97  66.40  0.218  60.48
  7    V1/JD3  0.605     129.8    25.88    9.76  57.43  0.142  52.82
```

WATER TEST #9

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1000.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 0.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S
1	V2/S5	0.279	101.9	0.0	2.00	0.00	0.018
2	V2/S7	0.391	104.2	0.0	5.00	0.00	0.052
3	V2/S4	0.558	116.6	0.0	13.00	0.00	0.155
4	V2/JD1	0.558	111.3	0.0	12.00	0.00	0.136
5	V2/JD2	0.558	103.9	0.0	10.00	0.00	0.130
6	V2/S3	0.838	117.0	0.0	39.00	0.00	0.630
7	V2/JD3	0.838	112.7	0.0	38.00	0.00	0.608

WATER TEST #10

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1020.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 1.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	104.4	27.66	1.60	64.72	0.022	64.15
2	V2/S7	0.391	103.0	12.11	5.05	69.10	0.060	67.46
3	V2/S4	0.558	116.9	5.89	16.14	71.12	0.204	65.56
4	V2/JD1	0.558	110.4	7.79	10.28	63.95	0.124	59.82
5	V2/JD2	0.558	110.1	7.02	11.06	63.69	0.133	59.17
6	V2/S3	0.838	127.2	2.84	44.70	83.51	0.828	70.18
7	V2/JD3	0.838	117.7	2.87	35.12	78.27	0.555	66.50

WATER TEST #11

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1048.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	108.4	34.71	2.81	57.35	0.044	56.12
2	V2/S7	0.391	108.3	25.91	5.33	65.82	0.075	63.90
3	V2/S4	0.558	117.1	10.54	15.12	66.68	0.197	60.75
4	V2/JD1	0.558	113.0	12.46	11.04	57.46	0.140	52.18
5	V2/JD2	0.558	114.5	15.46	10.37	61.96	0.135	57.56
6	V2/S3	0.838	125.9	5.28	45.25	82.36	0.864	67.77
7	V2/JD3	0.838	119.0	5.91	34.57	74.89	0.555	61.63

WATER TEST #12

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1082.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	106.3	38.67	4.25	47.86	0.070	45.55
2	V2/S7	0.391	106.9	40.87	5.09	57.74	0.088	55.47
3	V2/S4	0.558	117.9	21.07	14.00	69.47	0.202	64.50
4	V2/JD1	0.558	113.4	24.18	9.96	57.30	0.142	52.58
5	V2/JD2	0.558	113.2	23.99	10.26	59.36	0.147	54.72
6	V2/S3	0.838	126.6	9.80	41.95	83.40	0.789	71.41
7	V2/JD3	0.838	120.1	11.32	34.59	79.02	0.586	67.93

WATER TEST #13

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1000.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S
1	V2/S5	0.279	89.9	0.00	2.20	0.00	0.070
2	V2/S7	0.391	91.1	0.00	5.30	0.00	0.088
3	V2/S4	0.558	92.5	0.00	16.00	0.00	0.202
4	V2/JD1	0.558	89.8	0.00	12.20	0.00	0.142
5	V2/JD2	0.558	90.8	0.00	11.10	0.00	0.147
6	V2/S3	0.838	98.6	0.00	44.00	0.00	0.789
7	V2/JD3	0.838	98.3	0.00	37.00	0.00	0.586

WATER TEST #14

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1020.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 1.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	87.8	25.49	1.65	61.60	0.022	60.96
2	V2/S7	0.391	87.4	10.38	5.50	63.84	0.065	61.74
3	V2/S4	0.558	96.5	5.69	16.76	67.58	0.212	61.05
4	V2/JD1	0.558	92.5	6.92	11.21	58.94	0.135	53.76
5	V2/JD2	0.558	93.0	6.76	11.85	60.48	0.143	55.16
6	V2/S3	0.838	103.9	2.75	43.78	80.13	0.796	64.66
7	V2/JD3	0.838	98.4	2.76	34.97	74.38	0.550	60.61

WATER TEST #15

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1050.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	92.6	32.89	2.77	54.17	0.042	52.86
2	V2/S7	0.391	90.4	24.87	5.15	62.60	0.072	60.56
3	V2/S4	0.558	96.2	13.46	15.20	65.75	0.204	59.62
4	V2/JD1	0.558	92.1	16.69	10.33	56.88	0.136	51.91
5	V2/JD2	0.558	90.2	16.19	10.83	57.63	0.142	52.49
6	V2/S3	0.838	102.0	6.29	43.69	79.92	0.817	64.35
7	V2/JD3	0.838	96.3	7.18	34.65	74.59	0.563	61.12

WATER TEST #16

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1085.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 6.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	94.8	37.78	4.19	45.86	0.068	43.50
2	V2/S7	0.391	88.2	38.24	5.33	55.77	0.089	53.28
3	V2/S4	0.558	93.1	20.33	14.81	64.56	0.213	58.40
4	V2/JD1	0.558	88.7	22.92	10.18	51.95	0.143	46.51
5	V2/JD2	0.558	89.7	22.39	10.79	54.27	0.151	48.74
6	V2/S3	0.838	105.8	10.00	42.77	79.62	0.813	64.39
7	V2/JD3	0.838	95.5	11.48	32.62	73.89	0.535	61.25

WATER TEST #17

FEED PRESSURE = 138 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1048.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 0.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V3/S5	0.397	60.2	19.12	7.94	67.98	0.106	65.22
2	V3/S7	0.555	63.7	10.76	18.33	75.01	0.249	69.41
3	V3/S4	0.794	73.0	5.44	45.61	83.80	0.879	70.22
4	V3/JD1	0.794	70.1	5.86	35.58	76.70	0.581	63.83
5	V3/JD2	0.794	68.6	5.81	36.45	76.16	0.602	62.49
6	V3/S3	1.190	85.7	3.24	79.47	93.24	3.963	67.09
7	V3/JD3	1.190	82.0	3.58	70.49	97.92	2.473	92.94

TABLE C-2 BENTONITE DRILLING FLUID RECOVERY RESULTS

MUD TEST #1

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1049.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1063.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 1.0%
VISCOSITY = 33.9 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	165.5	4.97	2.35	14.59	0.025	12.54
2	V1/S7	0.282	170.1	3.51	4.35	20.14	0.047	16.51
3	V1/S4	0.403	175.1	2.08	9.81	25.67	0.110	17.59
4	V1/JD1	0.403	169.3	2.63	5.94	19.04	0.064	13.93

MUD TEST #2

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1049.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1101.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 40.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	167.6	7.18	2.88	6.40	0.031	3.63
2	V1/S7	0.282	167.5	6.67	5.01	10.30	0.055	5.57
3	V1/S4	0.403	171.3	5.13	10.82	16.73	0.124	6.63
4	V1/JD1	0.403	172.3	5.04	6.57	11.88	0.072	5.68

MUD TEST #3

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1049.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1147.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 6.0%
VISCOSITY = 27.0 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	157.0	15.66	2.42	6.77	0.028	4.46
2	V1/S7	0.282	165.3	13.44	4.34	10.17	0.049	6.09
3	V1/S4	0.403	165.8	10.22	9.96	16.96	0.116	7.77
4	V1/JD1	0.403	158.1	10.62	6.68	11.48	0.075	5.14

MUD TEST #4

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1030.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1085.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 11.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	160.7	32.43	1.18	17.92	0.017	16.94
2	V1/S7	0.282	161.2	31.05	1.79	25.66	0.029	24.30
3	V1/S4	0.403	159.7	15.31	6.07	35.49	0.075	31.32
4	V1/JD1	0.403	159.5	23.46	2.46	24.96	0.032	23.07
6	V1/S3	0.605	162.8	7.48	19.07	50.19	0.250	38.46

MUD TEST #5

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1030.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1075.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 11.8 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.2[illegible]	114.2	25.14	2.87	31.87	0.039	29.86
2	V2/S7	0.391	115.3	13.14	7.45	37.53	0.091	32.50
3	V2/S4	0.559	115.9	7.26	19.49	49.57	0.256	37.36
4	V3/S5	0.399	68.2	7.81	11.95	33.93	0.144	24.96
6	V2/S7	0.555	70.7	5.71	23.40	46.91	0.317	30.69

MUD TEST #6

FEED PRESSURE = 276 kPa MUD WEIGHT: = 1030.00 kg/m3 W/O SOLIDS
NO EXTENSION 1085.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 12.3 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	165.2	43.79	0.87	22.67	0.015	21.99
2	V1/S7	0.282	166.9	35.54	1.41	26.93	0.022	25.88
3	V1/S4	0.403	155.0	23.70	3.62	37.53	0.048	35.18
4	V1/S3	0.605	158.7	8.56	17.08	52.63	0.221	42.87

MUD TEST #7

FEED PRESSURE = 276 kPa MUD WEIGHT: = 1030.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1087.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 12.3 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V2/S5	0.279	112.5	34.49	2.17	38.92	0.033	37.57
2	V2/S7	0.391	108.5	18.98	5.75	44.67	0.074	41.29
3	V2/S4	0.559	112.5	8.86	17.38	55.86	0.227	46.57

MUD TEST #8

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1000.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1041.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 1.0 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	156.2	44.54	1.60	44.74	0.029	43.84
2	V1/S7	0.282	158.9	43.88	2.02	54.47	0.036	53.53
3	V1/S4	0.403	154.1	36.37	2.94	60.14	0.047	58.93

MUD TEST #9

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1006 kg/m3 W/O SOLIDS
WITH EXTENSION 1051.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 1.3 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	163.9	39.85	1.83	42.31	0.031	41.23
2	V1/S7	0.282	158.5	45.23	1.86	51.13	0.034	50.20
3	V1/S4	0.403	153.7	33.34	3.32	58.54	0.051	57.12

MUD TEST #10

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FEED PRESSURE = 207 kPa MUD WEIGHT: = 1012.00 kg/m3 W/O SOLIDS

WITH EXTENSION 1057.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%

VISCOSITY = 2.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	160.8	40.41	1.63	38.16	0.027	37.14
2	V1/S7	0.282	158.4	37.05	2.33	46.43	0.037	45.15
3	V1/S4	0.403	155.0	31.32	3.47	54.91	0.052	53.29

MUD TEST #11

============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1020.00 kg/m3 W/O SOLIDS

WITH EXTENSION 1064.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%

VISCOSITY = 4.8 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	159.1	41.52	1.30	31.68	0.022	30.78
2	V1/S7	0.282	156.2	43.93	1.57	40.76	0.028	39.82
3	V1/S4	0.403	156.3	24.57	4.47	49.54	0.061	47.18

MUD TEST #12

============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1027.00 kg/m3 W/O SOLIDS

WITH EXTENSION 1069.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%

VISCOSITY = 7.8 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	161.0	38.64	1.30	28.63	0.031	27.69
2	V1/S7	0.282	161.9	33.84	2.04	35.97	0.021	34.64
3	V1/S4	0.403	164.9	19.58	5.30	44.59	0.068	41.49

MUD TEST #13

============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1038.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1074.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 18.8 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	163.5	28.20	1.28	17.16	0.018	16.09
2	V1/S7	0.282	169.4	19.63	2.55	21.20	0.032	19.14
3	V1/S4	0.403	168.4	10.47	7.13	28.02	0.084	22.49

MUD TEST #14

============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1044.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1088.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 29.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	171.5	14.96	1.93	11.43	0.023	9.69
2	V1/S7	0.282	168.1	10.92	3.55	14.54	0.040	11.39
3	V1/S4	0.403	175.8	7.00	8.43	21.53	0.097	14.31

MUD TEST #15

============

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1049.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1095.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 40.8 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	182.9	8.47	2.57	8.17	0.028	5.75
2	V1/S7	0.282	175.9	6.43	4.74	11.16	0.052	6.74
3	V1/S4	0.403	176.1	5.00	9.85	18.61	0.112	9.72

MUD TEST #16

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FEED PRESSURE = 207 kPa MUD WEIGHT: = 1055.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1099.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 63.3 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	204.3	7.27	1.47	3.90	0.016	2.47
2	V1/S7	0.282	181.6	4.43	6.17	10.00	0.067	4.08
3	V1/S4	0.403	185.3	3.97	11.93	17.09	0.137	5.86

MUD TEST #17

===========

FEED PRESSURE = 207 kPa MUD WEIGHT: = 1061.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1103.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 98.5 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	204.8	3.42	3.46	4.33	0.036	0.90
2	V1/S7	0.282	200.3	3.58	4.91	7.15	0.052	2.36
3	V1/S4	0.403	206.9	3.17	9.83	12.35	0.110	2.79

MUD TEST #18

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FEED PRESSURE = 207 kPa MUD WEIGHT: = 1068.00 kg/m3 W/O SOLIDS
WITH EXTENSION 1107.00 kg/m3 W/SOLIDS

FEED SOLIDS CONCENTRATION = 3.0%
VISCOSITY = 155.0 (cp)

CUT	VORTEX/ SPIGOT	Du/Do	FEED (Q) FLOW RATE (L/min)	SOLIDS U/F (%)	Rf (%)	Rs (%)	S	CORR. EFF. (%)
1	V1/S5	0.202	193.7	3.42	3.95	4.50	0.041	0.57
2	V1/S7	0.282	207.2	3.58	7.48	9.32	0.081	1.99
3	V1/S4	0.403	195.7	3.17	14.58	15.69	0.171	1.30

TABLE C-3

RHEOLOGICAL DATA FROM THE WATER-ONLY AND BENTONITE DRILLING FLUID EXPERIMENTS

	FANN DIAL READINGS W/O SOLIDS						GEL STRENGTHS		FANN DIAL READINGS W/ SOLIDS						GEL STRENGTHS	
	600	300	200	100	6	3	10"	10'	600	300	200	100	6	3	10"	10'
WATER TEST																
#1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

ALL THE WATER TESTS HAD IDENTICAL FANN VISCOMETER NUMBERS

MUD TEST																
#1	67.8	43.2	34.5	22.9	8.0	8.0	13.5	27.0	68.5	45.0	34.5	23.2	8.5	8.5	12.0	25.0
#2	81.0	55.0	45.0	32.0	17.0	15.0	19.0	40.0	83.0	57.0	47.5	33.0	18.0	16.0	18.0	39.5
#3	54.0	35.0	26.5	18.5	9.5	8.0	11.0	24.0	59.0	38.0	30.0	21.0	11.0	9.0	10.0	23.5
#4	23.0	13.9	10.5	6.7	1.5	1.0	1.5	9.5	25.3	14.5	10.8	6.5	1.9	0.5	1.0	8.0
#5	23.5	14.5	10.5	6.5	1.5	1.0	2.5	9.0	26.7	15.6	11.8	6.3	1.5	1.0	2.0	9.0
#6	24.6	15.0	11.5	7.2	2.0	1.0	2.0	10.0	25.0	15.0	11.5	7.0	1.5	1.0	2.0	10.0
#7	24.6	15.0	11.0	7.0	2.0	1.5	1.5	7.0	25.0	15.0	11.5	7.0	1.5	1.0	1.5	7.5
#8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5
#9	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0	1.0	1.5
#10	5.0	2.5	1.5	0.5	0.5	0.5	1.0	1.0	5.0	2.5	1.5	0.5	0.5	0.5	1.0	1.5
#11	9.5	5.5	4.0	2.2	1.0	1.0	1.0	1.5	10.0	6.0	4.0	2.5	1.0	1.0	1.5	2.0
#12	15.5	9.5	6.9	4.2	1.0	0.5	1.0	5.0	16.5	10.0	7.5	4.5	1.0	1.0	2.0	6.0
#13	37.5	24.5	18.5	12.2	5.5	4.8	5.0	16.0	39.0	26.0	19.0	13.3	6.0	5.0	5.5	15.5
#14	59.0	39.0	30.5	22.2	11.5	10.0	13.0	33.0	60.0	40.0	32.0	22.6	12.0	10.5	13.0	32.0
#15	81.5	57.0	46.5	35.5	17.0	15.5	25.0	45.0	82.0	57.0	47.0	36.5	18.0	16.0	25.5	44.0
#16	126.5	92.0	77.5	60.0	28.0	26.5	43.0	55.0	129.0	93.0	78.0	61.0	29.0	27.0	43.0	55.0
#17	197.0	147.5	124.5	90.0	30.5	29.0	70.0	90.0	200.0	150.0	125.0	91.0	31.0	29.5	69.0	91.0
#18	310.0	239.0	194.5	138.0	37.0	35.0	118.0	142.0	301.0	235.0	195.0	140.0	38.0	35.5	117.0	141.0

APPARENT VISCOSITY = 600 READING DIVIDED BY 2
PLASTIC VISCOSITY = (600 - 300) READING
BINGHAM YIELD POINT = 300 READING - PLASTIC VISCOSITY
TRUE YIELD POINT = (3/4) OF THE BINGHAM YIELD

Appendix D

Water-Only and Bentonite Partition Curve Data

TABLE D-1 PARTITION CURVE RESULTS FROM THE WATER ONLY DRILLING FLUID TESTS

D25c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 25%
D50c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 50%
D75c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 75%
Ep = PROBABLE ERROR
I = IMPERFECTION
m = SHARPNESS OF SEPARATION

VORTEX/ SPIGOT	D25c	D50c	D75c	Ep	I	m
WATER TEST #2:						
V1\S5	12.90	14.90	18.00	2.55	0.171	4.46
V1\S7	10.40	13.90	17.20	3.40	0.245	3.15
V1\JD1	6.65	10.30	16.00	4.68	0.454	1.71
V1\JD2	15.00	17.00	19.30	2.15	0.126	5.95
V1\S4	4.35	6.15	8.65	2.15	0.350	2.20
V1\JD3	4.10	6.30	9.70	2.80	0.444	1.75
V1\S3	3.10	5.50	9.60	3.25	0.591	1.32
WATER TEST #3:						
V1\S5	16.50	18.70	23.00	3.25	0.174	4.45
V1\S7	13.90	16.20	18.60	2.35	0.145	5.36
V1\JD1	11.50	16.70	21.50	5.00	0.299	2.57
V1\JD2	14.40	19.00	24.00	4.80	0.253	3.09
V1\S4	4.75	6.85	10.00	2.63	0.383	2.02
V1\JD3	3.35	5.90	10.00	3.33	0.564	1.38
V1\S3	3.65	5.80	9.35	2.85	0.491	1.57
WATER TEST #4:						
V1\S5	25.00	29.00	35.40	5.20	0.179	4.33
V1\S7	20.50	23.00	27.50	3.50	0.152	5.09
V1\JD1	16.00	17.50	19.00	1.50	0.086	8.70
V1\JD2	22.00	25.00	29.00	3.50	0.140	5.56
V1\S4	10.40	15.20	18.40	4.00	0.263	2.96
V1\JD3	5.00	7.67	12.50	3.75	0.489	1.57
V1\S3	3.67	6.00	9.70	3.01	0.503	1.54

WATER TEST #10:

V2\S5	4.70	7.20	12.30	3.80	0.528	1.46
V2\S7	4.40	6.80	11.90	3.75	0.551	1.41
V2\JD1	3.93	6.00	9.15	2.61	0.435	1.75
V2\JD2	4.09	6.25	9.50	2.71	0.433	1.79
V2\S4	3.17	5.30	8.45	2.64	0.498	1.54
V2\JD3	2.35	4.65	8.30	2.98	0.640	1.22
V2\S3	2.51	4.82	8.50	3.00	0.621	1.26

WATER TEST #11:

V2\S5	8.50	13.70	17.00	4.25	0.310	2.49
V2\S7	4.80	7.90	13.50	4.35	0.551	1.41
V2\JD1	4.25	6.20	9.00	2.38	0.383	2.02
V2\JD2	4.10	6.10	9.25	2.58	0.422	1.83
V2\S4	3.00	5.25	8.50	2.75	0.524	1.49
V2\JD3	2.85	5.20	8.20	2.68	0.514	1.52
V2\S3	2.30	4.30	7.60	2.65	0.616	1.26

WATER TEST #12:

V2\S5	16.50	20.00	24.50	4.00	0.200	3.87
V2\S7	14.00	16.50	19.30	2.65	0.161	4.82
V2\JD1	6.10	10.00	16.00	4.95	0.495	1.54
V2\JD2	5.15	7.50	12.00	3.43	0.457	1.68
V2\S4	3.60	5.65	9.00	2.70	0.478	1.61
V2\JD3	2.87	5.00	8.67	2.90	0.580	1.34
V2\S3	2.35	4.60	8.30	2.98	0.647	1.20

TABLE D-2 PARTITION CURVE RESULTS FROM THE BENTONITE DRILLING FLUID TESTS

D25c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 25%
D50c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 50%
D75c = CORRECTED CUT SIZE FOR FRACTIONAL RECOVERY AT 75%
Ep = PROBABLE ERROR
I = IMPERFECTION OF THE PARTITION CURVE
m = SHARPNESS OF SEPARATION

VORTEX/ SPIGOT	D25c	D50c	D75c	Ep	I	m
MUD TEST #1:						
V1\S5	63.00	81.00	110.00	23.50	0.290	2.66
V1\S7	60.00	78.00	106.00	23.00	0.295	2.61
V1\JD1	60.00	80.00	118.00	29.00	0.363	2.12
V1\S4	59.00	73.00	106.00	23.50	0.322	2.32
MUD TEST #2:						
V1\S5	81.00	112.00	140.00	29.50	0.263	2.93
V1\S7	72.00	106.00	145.00	36.50	0.344	2.12
V1\JD1	69.00	90.00	125.00	28.00	0.311	2.48
V1\S4	66.00	100.00	135.00	34.50	0.345	2.23
MUD TEST #3:						
V1\S5	72.00	99.00	142.00	35.00	0.354	2.18
V1\S7	65.00	89.00	127.00	31.00	0.348	2.21
V1\JD1	65.00	97.00	136.00	35.50	0.366	2.10
V1\S4	60.00	85.00	127.00	33.50	0.394	1.96
MUD TEST #4:						
V1\S5	30.00	37.00	44.00	7.00	0.189	4.09
V1\S7	27.00	33.50	43.00	8.00	0.239	3.23
V1\JD1	28.00	34.00	43.50	7.75	0.228	3.39
V1\S4	23.00	30.00	40.00	8.50	0.283	2.72
V1\S3	18.50	24.50	35.00	8.25	0.337	2.29
MUD TEST #5:						
V2\S5	21.00	27.50	39.00	9.00	0.327	2.36
V2\S7	21.00	28.00	38.00	8.50	0.304	2.53
V2\S4	17.00	23.00	33.00	8.00	0.348	2.21
V3\S5	24.00	37.50	45.00	10.50	0.280	2.75
V3\S7	17.00	29.00	36.50	9.75	0.336	2.29
MUD TEST #6:						
V1\S5	32.00	37.00	44.00	6.00	0.162	4.77
V1\S7	28.00	34.00	39.70	5.85	0.172	4.50
V1\S4	22.50	28.10	35.00	6.25	0.222	3.48
V1\S3	18.60	24.50	31.50	6.45	0.263	2.93

MUD TEST #7:						
V2\S5	21.50	26.50	32.40	5.45	0.206	3.75
V2\S7	19.00	25.00	32.00	6.50	0.260	2.97
V2\S4	18.00	22.50	28.00	5.00	0.222	3.48
MUD TEST #8:						
V1\S5	16.60	19.80	23.50	3.45	0.174	4.46
V1\S7	13.70	16.00	18.00	2.15	0.134	5.81
V1\S4	5.20	7.90	13.80	4.30	0.544	1.42
MUD TEST #9:						
V1\S5	17.50	21.10	25.00	3.75	0.178	4.35
V1\S7	14.00	16.60	19.50	2.75	0.166	4.67
V1\S4	5.00	7.40	12.00	3.50	0.473	1.63
MUD TEST #10:						
V1\S5	21.00	23.00	28.00	3.50	0.152	5.11
V1\S7	14.00	17.50	22.50	4.25	0.243	3.18
V1\S4	13.60	17.00	20.00	3.20	0.188	4.12
MUD TEST #11:						
V1\S5	22.50	27.50	33.50	5.50	0.200	3.87
V1\S7	19.70	23.50	28.00	4.15	0.177	4.38
V1\S4	7.20	13.00	19.00	5.90	0.454	1.70
MUD TEST #12:						
V1\S5	28.00	33.50	39.00	5.50	0.164	4.73
V1\S7	22.50	28.00	35.00	6.25	0.223	3.46
V1\S4	19.00	24.00	31.00	6.00	0.250	3.09
MUD TEST #13:						
V1\S5	38.00	45.00	58.00	10.00	0.222	3.47
V1\S7	36.00	43.00	58.00	11.00	0.256	3.01
V1\S4	31.50	42.00	53.00	10.75	0.256	3.01
MUD TEST #14:						
V1\S5	52.00	62.50	74.00	11.00	0.176	4.41
V1\S7	46.00	60.00	71.00	12.50	0.208	3.72
V1\S4	42.50	58.00	71.00	14.25	0.246	3.14
MUD TEST #15:						
V1\S5	61.00	80.00	121.00	30.00	0.375	2.06
V1\S7	61.00	74.00	103.00	21.00	0.284	2.71
V1\JD1	63.00	82.00	120.00	28.50	0.348	2.21
V1\S4	59.00	75.00	120.00	30.50	0.407	1.89

MUD TEST #16:

V1\S5	98.00	130.00	152.00	27.00	0.208	3.72
V1\S7	88.00	112.00	136.00	24.00	0.214	3.61
V1\JD1	90.00	133.00	151.00	30.50	0.229	3.37
V1\S4	90.00	120.00	130.00	20.00	0.167	4.65

MUD TEST #17:

V1\S5	141.00	155.00	161.00	10.00	0.065	12.16
V1\S7	140.00	151.00	160.00	10.00	0.066	12.18
V1\JD1	140.00	151.00	158.00	9.00	0.060	12.63
V1\S4	136.00	150.00	159.00	11.50	0.077	10.19

MUD TEST #18: CURVES ARE NO GOOD

V1\S5	109.00	114.00	121.00	6.00	0.053
V1\S7	107.50	112.00	117.50	5.00	0.045
V1\JD1	107.00	110.00	116.00	4.50	0.041
V1\S4	106.50	108.50	113.50	3.50	0.032

TABLE D-3 PARTITION CURVE DATA FROM THE WATER-ONLY DRILLING FLUID TESTS

PARTICLE SIZE ANALYSIS FOR WATER TEST #2

INLET PRESSURE = 207 kPa
SOLIDS = 1%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	21.44	0.23	45.00	49.00	4.55	12.40	0.10	12.50	99.22	99.21
7.81	19.84	0.53	34.04	39.52	9.76	11.48	0.22	11.70	98.09	98.06
14.01	28.26	1.69	23.72	28.88	17.51	16.35	0.71	17.06	95.82	95.75
14.35	22.32	6.91	15.47	19.59	17.94	12.91	2.91	15.82	81.59	81.28
5.92	3.63	9.68	11.34	13.40	7.40	2.10	4.08	6.18	33.97	32.87
34.27	4.51	80.96		3.90	42.84	2.61	34.13	36.74	7.10	5.55

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	22.25	0.29	45.00	49.00	4.55	13.74	0.13	13.87	99.06	99.05
7.81	19.14	0.51	34.04	39.52	9.76	11.82	0.23	12.05	98.10	98.08
14.01	27.14	1.64	23.72	28.88	17.51	16.76	0.74	17.50	95.79	95.74
14.35	21.44	5.30	15.47	19.59	17.94	13.24	2.38	15.63	84.75	84.58
5.92	4.44	6.96	11.34	13.40	7.40	2.74	3.13	5.87	46.71	46.11
34.27	5.59	70.33		3.90	42.84	3.45	31.62	35.07	9.84	8.84

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	10.02	0.45	45.00	49.00	4.55	6.06	0.18	6.24	97.15	97.04
7.81	10.56	0.24	34.04	39.52	9.76	6.39	0.09	6.48	98.54	98.48
14.01	26.93	2.89	23.72	28.88	17.51	16.29	1.14	17.43	93.45	93.19
14.35	24.72	2.44	15.47	19.59	17.94	14.96	0.96	15.92	93.95	93.70
5.92	11.15	0.79	11.34	13.40	7.40	6.75	0.31	7.06	95.58	95.40
34.27	16.62	93.19		3.90	42.84	10.06	36.81	46.87	21.46	18.27

CUT V1JD1

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	7.33	0.00	45.00	49.00	4.55	3.64	0.00	3.64	100.00	100.00
7.81	17.37	0.00	34.04	39.52	9.76	8.62	0.00	8.62	100.00	100.00
14.01	32.49	0.34	23.72	28.88	17.51	16.12	0.17	16.29	98.95	98.93
14.35	28.21	1.40	15.47	19.59	17.94	13.99	0.71	14.70	95.20	95.14
5.92	10.29	3.99	11.34	13.40	7.40	5.10	2.01	7.11	71.74	71.39
34.27	4.31	94.27		3.90	42.84	2.14	47.51	49.65	4.31	3.12

CUT V1JD2

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	13.81	0.00	45.00	49.00	4.55	5.91	0.00	5.91	100.00	100.00
7.81	13.49	0.06	34.04	39.52	9.76	5.77	0.03	5.80	99.41	99.40
14.01	35.67	0.37	23.72	28.88	17.51	15.25	0.21	15.46	98.63	98.61
14.35	31.40	4.09	15.47	19.59	17.94	13.43	2.34	15.77	85.15	84.98
5.92	3.71	8.49	11.34	13.40	7.40	1.59	4.86	6.45	24.61	23.73
34.27	1.92	86.99		3.90	42.84	0.82	49.79	50.61	1.62	0.47

CUT V1S3

			53.00							
3.64	5.67	0.36	45.00	49.00	4.55	5.00	0.13	5.14	97.42	96.90
7.81	6.61	0.22	34.04	39.52	9.76	5.83	0.08	5.91	98.63	98.35
14.01	16.73	0.74	23.72	28.88	17.51	14.76	0.27	15.04	98.19	97.82
14.35	18.13	2.21	15.47	19.59	17.94	16.00	0.81	16.81	95.17	94.19
5.92	6.86	1.67	11.34	13.40	7.40	6.05	0.61	6.67	90.80	88.92
34.27	26.00	74.80		3.90	42.84	22.94	27.49	50.43	45.50	34.41

CUT V1JD3

			53.00							
3.64	7.70	0.00	45.00	49.00	4.55	5.13	0.00	5.13	100.00	100.00
7.81	8.91	0.00	34.04	39.52	9.76	5.94	0.00	5.94	100.00	100.00
14.01	25.05	0.59	23.72	28.88	17.51	16.69	0.20	16.89	98.83	98.69
14.35	26.06	2.53	15.47	19.59	17.94	17.37	0.84	18.21	95.37	94.79
5.92	11.16	2.18	11.34	13.40	7.40	7.44	0.73	8.16	91.09	89.99
34.27	21.12	94.70		3.90	42.84	14.07	31.59	45.67	30.82	22.24

PARTICLE SIZE ANALYSIS FOR WATER TEST #3

INLET PRESSURE = 207 kPa

SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	23.70	0.25	45.00	49.00	4.55	10.60	0.14	10.74	98.71	98.69
7.81	17.64	0.34	34.04	39.52	9.76	7.89	0.19	8.08	97.67	97.64
14.01	33.75	2.08	23.72	28.88	17.51	15.10	1.15	16.25	92.93	92.81
14.35	18.19	16.50	15.47	19.59	17.94	8.14	9.12	17.26	47.16	46.30
5.92	0.99	12.45	11.34	13.40	7.40	0.44	6.88	7.32	6.05	4.52
34.27	5.73	68.38		3.90	42.84	2.56	37.79	40.35	6.35	4.83

CUT V1S7

			53.00							
3.64	17.91	0.24	45.00	49.00	4.55	9.76	0.11	9.86	98.89	98.87
7.81	15.79	0.30	34.04	39.52	9.76	8.60	0.14	8.74	98.42	98.38
14.01	31.25	1.37	23.72	28.88	17.51	17.02	0.62	17.64	96.47	96.40
14.35	25.40	7.44	15.47	19.59	17.94	13.84	3.39	17.22	80.33	79.93
5.92	3.91	10.89	11.34	13.40	7.40	2.13	4.96	7.09	30.05	28.61
34.27	5.74	79.76		3.90	42.84	3.13	36.31	39.44	7.93	6.03

CUT V1S4

			53.00							
3.64	9.67	0.00	45.00	49.00	4.55	5.67	0.00	5.67	100.00	100.00
7.81	9.31	0.00	34.04	39.52	9.76	5.46	0.00	5.46	100.00	100.00
14.01	24.96	0.58	23.72	28.88	17.51	14.63	0.24	14.87	98.38	98.31
14.35	23.99	2.26	15.47	19.59	17.94	14.06	0.94	14.99	93.76	93.48
5.92	17.40	2.53	11.34	13.40	7.40	10.20	1.05	11.24	90.68	90.26
34.27	14.67	94.63		3.90	42.84	8.60	39.18	47.77	17.99	14.28

CUT V1JD1

			53.00							
3.64	12.36	0.00	45.00	49.00	4.55	4.87	0.00	4.87	100.00	100.00
7.81	10.87	0.00	34.04	39.52	9.76	4.28	0.00	4.28	100.00	100.00
14.01	28.19	0.49	23.72	28.88	17.51	11.10	0.30	11.40	97.39	97.33
14.35	29.49	7.05	15.47	19.59	17.94	11.61	4.27	15.89	73.10	72.47
5.92	13.49	12.23	11.34	13.40	7.40	5.31	7.41	12.73	41.74	40.38
34.27	5.60	80.23		3.90	42.84	2.21	48.64	50.84	4.34	2.11

CUT V1JD2

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	5.07	0.00	45.00	49.00	4.55	2.99	0.00	2.99	100.00	100.00
7.81	6.96	0.00	34.04	39.52	9.76	4.10	0.00	4.10	100.00	100.00
14.01	20.68	0.43	23.72	28.88	17.51	12.19	0.18	12.37	98.57	98.42
14.35	15.51	1.96	15.47	19.59	17.94	9.15	0.80	9.95	91.92	91.07
5.92	12.29	2.49	11.34	13.40	7.40	7.25	1.02	8.27	87.64	86.35
34.27	39.49	95.12		3.90	42.84	23.29	39.03	62.31	37.37	30.82

CUT V1S3

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	4.84	0.00	45.00	49.00	4.55	3.14	0.00	3.14	100.00	100.00
7.81	6.12	0.00	34.04	39.52	9.76	3.97	0.00	3.97	100.00	100.00
14.01	19.88	0.35	23.72	28.88	17.51	12.90	0.14	13.04	98.90	98.69
14.35	22.98	1.75	15.47	19.59	17.94	14.91	0.71	15.62	95.42	94.55
5.92	11.84	1.56	11.34	13.40	7.40	7.68	0.64	8.32	92.34	90.87
34.27	34.34	82.34		3.90	42.84	22.28	33.63	55.91	39.84	28.33

CUT V1JD3

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	7.70	0.00	45.00	49.00	4.55	5.13	0.00	5.13	100.00	100.00
7.81	8.91	0.00	34.04	39.52	9.76	5.94	0.00	5.94	100.00	100.00
14.01	25.05	0.59	23.72	28.88	17.51	16.69	0.20	16.89	98.83	98.69
14.35	26.06	2.53	15.47	19.59	17.94	17.37	0.84	18.21	95.37	94.79
5.92	11.16	2.18	11.34	13.40	7.40	7.44	0.73	8.16	91.09	89.99
34.27	21.12	94.70		3.90	42.84	14.07	31.59	45.67	30.82	22.24

PARTICLE SIZE ANALYSIS FOR WATER TEST #4

INLET PRESSURE = 207 kPa

SOLIDS = 6%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	32.56	0.34	45.00	49.00	4.55	9.50	0.24	9.74	97.53	97.46
7.81	29.69	1.64	34.04	39.52	9.76	8.66	1.16	9.82	88.17	87.85
14.01	24.97	13.64	23.72	28.88	17.51	7.28	9.66	16.94	42.98	41.41
14.35	4.78	22.14	15.47	19.59	17.94	1.39	15.68	17.08	8.17	5.63
5.92	0.86	9.86	11.34	13.40	7.40	0.25	6.98	7.23	3.47	0.80
34.27	7.14	52.38		3.90	42.84	2.08	37.10	39.18	5.32	2.70

CUT V1S7

			53.00							
3.64	26.44	0.34	45.00	49.00	4.55	11.24	0.20	11.43	98.29	98.23
7.81	26.40	0.72	34.04	39.52	9.76	11.22	0.41	11.63	96.44	96.32
14.01	32.29	6.13	23.72	28.88	17.51	13.72	3.52	17.25	79.56	78.84
14.35	7.69	21.40	15.47	19.59	17.94	3.27	12.31	15.57	20.99	18.20
5.92	0.83	10.51	11.34	13.40	7.40	0.35	6.04	6.40	5.52	2.18
34.27	6.35	60.90		3.90	42.84	2.70	35.02	37.72	7.16	3.88

CUT V1S4

			53.00							
3.64	12.52	0.00	45.00	49.00	4.55	7.14	0.00	7.14	100.00	100.00
7.81	12.78	0.39	34.04	39.52	9.76	7.28	0.17	7.45	97.75	97.65
14.01	30.91	1.11	23.72	28.88	17.51	17.62	0.48	18.10	97.36	97.25
14.35	27.22	5.21	15.47	19.59	17.94	15.52	2.24	17.76	87.38	86.83
5.92	7.81	10.77	11.34	13.40	7.40	4.45	4.63	9.08	49.01	46.76
34.27	8.76	82.52		3.90	42.84	4.99	35.48	40.48	12.34	8.46

CUT V1JD1

			53.00							
3.64	18.19	0.00	45.00	49.00	4.55	6.58	0.00	6.58	100.00	100.00
7.81	16.77	0.07	34.04	39.52	9.76	6.06	0.04	6.11	99.27	99.25
14.01	38.61	2.49	23.72	28.88	17.51	13.96	1.59	15.55	89.78	89.51
14.35	17.87	2.01	15.47	19.59	17.94	6.46	1.28	7.74	83.43	82.99
5.92	1.43	8.39	11.34	13.40	7.40	0.52	5.36	5.87	8.80	6.38
34.27	7.13	87.04		3.90	42.84	2.58	55.57	58.14	4.43	1.89

CUT V1JD2

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	20.65	0.06	45.00	49.00	4.55	6.31	0.04	6.35	99.34	99.33
7.81	17.75	0.13	34.04	39.52	9.76	5.42	0.09	5.51	98.36	98.32
14.01	39.83	4.35	23.72	28.88	17.51	12.17	3.02	15.19	80.12	79.60
14.35	12.97	19.62	15.47	19.59	17.94	3.96	13.62	17.59	22.54	20.52
5.92	0.94	9.65	11.34	13.40	7.40	0.29	6.70	6.99	4.11	1.61
34.27	7.86	66.19		3.90	42.84	2.40	45.96	48.36	4.97	2.49

CUT V1S3

			53.00							
3.64	8.63	0.00	45.00	49.00	4.55	6.06	0.00	6.06	100.00	100.00
7.81	8.83	0.49	34.04	39.52	9.76	6.20	0.15	6.35	97.70	97.26
14.01	23.70	1.34	23.72	28.88	17.51	16.65	0.40	17.05	97.66	97.21
14.35	23.33	3.58	15.47	19.59	17.94	16.39	1.06	17.46	93.90	92.73
5.92	10.61	2.72	11.34	13.40	7.40	7.45	0.81	8.26	90.21	88.33
34.27	24.90	91.87		3.90	42.84	17.49	27.32	44.82	39.04	27.33

CUT V1JD3

			53.00							
3.64	10.10	0.07	45.00	49.00	4.55	6.07	0.03	6.10	99.54	99.50
7.81	9.85	0.14	34.04	39.52	9.76	5.92	0.06	5.96	99.07	98.97
14.01	27.49	0.60	23.72	28.88	17.51	16.53	0.24	16.77	98.57	98.43
14.35	25.50	2.43	15.47	19.59	17.94	15.33	0.97	16.30	94.05	93.46
5.92	9.55	2.81	11.34	13.40	7.40	5.74	1.12	6.86	83.67	82.04
34.27	17.51	93.95		3.90	42.84	10.53	37.47	47.99	21.93	14.16

PARTICLE SIZE ANALYSIS FOR WATER TEST #10

INLET PRESSURE = 207 kPa

SOLIDS = 1%

CUT V2S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	17.16	0.09	45.00	49.00	4.55	11.11	0.04	11.15	99.60	99.59
7.81	17.62	0.17	34.04	39.52	9.76	11.40	0.08	11.49	99.27	99.26
14.01	25.88	0.77	23.72	28.88	17.51	16.75	0.38	17.13	97.78	97.74
14.35	22.05	2.27	15.47	19.59	17.94	14.27	1.12	15.39	92.71	92.59
5.92	7.33	2.52	11.34	13.40	7.40	4.74	1.25	5.99	79.20	78.86
34.27	9.96	65.54		3.90	42.84	6.45	32.40	38.85	16.59	15.24

CUT V2S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	19.21	0.12	45.00	49.00	4.55	13.27	0.08	13.35	99.39	99.36
7.81	16.84	0.17	34.04	39.52	9.76	11.64	0.11	11.75	99.03	98.97
14.01	25.06	0.61	23.72	28.88	17.51	17.32	0.41	17.73	97.68	97.56
14.35	21.17	1.74	15.47	19.59	17.94	14.63	1.17	15.80	92.58	92.19
5.92	6.71	1.57	11.34	13.40	7.40	4.64	1.06	5.69	81.43	80.45
34.27	11.01	41.68		3.90	42.84	7.61	28.07	35.67	21.33	17.14

CUT V2S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	8.06	0.00	45.00	49.00	4.55	5.73	0.00	5.73	100.00	100.00
7.81	6.51	0.00	34.04	39.52	9.76	4.63	0.00	4.63	100.00	100.00
14.01	21.27	0.48	23.72	28.88	17.51	15.13	0.16	15.29	98.94	98.74
14.35	20.29	2.39	15.47	19.59	17.94	14.43	0.80	15.23	94.73	93.71
5.92	13.02	1.94	11.34	13.40	7.40	9.26	0.65	9.91	93.42	92.15
34.27	30.85	81.09		3.90	42.84	21.94	27.26	49.20	44.59	33.93

CUT V2JD1

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	6.38	0.00	45.00	49.00	4.55	4.08	0.00	4.08	100.00	100.00
7.81	7.12	0.00	34.04	39.52	9.76	4.55	0.00	4.55	100.00	100.00
14.01	22.84	0.59	23.72	28.88	17.51	14.61	0.21	14.82	98.56	98.40
14.35	24.87	1.95	15.47	19.59	17.94	15.90	0.70	16.61	95.77	95.28
5.92	12.77	1.82	11.34	13.40	7.40	8.17	0.66	8.82	92.56	91.71
34.27	26.02	95.64		3.90	42.84	16.64	34.48	51.12	32.55	24.82

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CUT V1JD2
=========
 FEED   UNDER/ OVER/    SCREEN  ARIMEAN   FEED   UNDERFLOW  OVERFLOW   CALC.      Y        Yi
         FLOW   FLOW     SIZE    SIZE    FACTOR    FACTOR    FACTOR     FEED
(gms)   (gms)  (gms)     (um)    (um)     (%)       (%)        (%)      (%)      (%)      (%)
=====================   ===================================================================
                         53.00
  3.64   6.95   0.00     45.00   49.00     4.55      4.43      0.00      4.43   100.00   100.00
  7.81   7.99   0.00     34.04   39.52     9.76      5.09      0.00      5.09   100.00   100.00
 14.01  23.55   0.32     23.72   28.88    17.51     15.00      0.14     15.14    99.06    98.94
 14.35  24.40   1.37     15.47   19.59    17.94     15.54      0.61     16.15    96.22    95.75
  5.92  12.32   1.39     11.34   13.40     7.40      7.85      0.62      8.47    92.69    91.78
 34.27  24.79  78.47              3.90    42.84     15.79     34.94     50.73    31.12    22.56

CUT V2S3
========
                         53.00
  3.64   6.92   0.00     45.00   49.00     4.55      5.78      0.00      5.78   100.00   100.00
  7.81   6.17   0.00     34.04   39.52     9.76      5.15      0.00      5.15   100.00   100.00
 14.01  19.50   0.92     23.72   28.88    17.51     16.28      0.25     16.54    98.46    97.22
 14.35  19.49   3.04     15.47   19.59    17.94     16.28      0.84     17.12    95.09    91.13
  5.92  11.31   2.16     11.34   13.40     7.40      9.44      0.60     10.04    94.06    89.26
 34.27  36.61  53.58              3.90    42.84     30.57     14.80     45.37    67.38    41.02

CUT V2JD3
=========
                         53.00
  3.64   4.72   0.00     45.00   49.00     4.55      3.69      0.00      3.69   100.00   100.00
  7.81   6.23   0.00     34.04   39.52     9.76      4.88      0.00      4.88   100.00   100.00
 14.01  18.38   0.27     23.72   28.88    17.51     14.39      0.12     14.50    99.18    98.74
 14.35  18.28   1.22     15.47   19.59    17.94     14.31      0.54     14.84    96.39    94.44
  5.92   7.75   0.90     11.34   13.40     7.40      6.07      0.40      6.46    93.89    90.57
 34.27  44.64  47.11              3.90    42.84     34.94     20.68     55.62    62.82    42.69
```

PARTICLE SIZE ANALYSIS FOR WATER TEST #11

INLET PRESSURE = 207 kPa

SOLIDS = 3%

CUT V2S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	15.26	0.22	45.00	49.00	4.55	8.75	0.09	8.85	98.94	98.91
7.81	17.88	0.38	34.04	39.52	9.76	10.25	0.16	10.42	98.44	98.40
14.01	28.50	1.40	23.72	28.88	17.51	16.34	0.60	16.94	96.48	96.37
14.35	24.92	4.68	15.47	19.59	17.94	14.29	2.00	16.29	87.75	87.39
5.92	7.18	7.79	11.34	13.40	7.40	4.12	3.32	7.44	55.34	54.05
34.27	6.26	85.53		3.90	42.84	3.59	36.48	40.07	8.96	6.33

CUT V2S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	16.50	0.39	45.00	49.00	4.55	10.86	0.13	10.99	98.79	98.72
7.81	18.23	0.51	34.04	39.52	9.76	12.00	0.17	12.17	98.57	98.49
14.01	25.60	1.72	23.72	28.88	17.51	16.85	0.59	17.44	96.63	96.44
14.35	21.96	4.45	15.47	19.59	17.94	14.45	1.52	15.98	90.48	89.94
5.92	7.27	4.37	11.34	13.40	7.40	4.79	1.49	6.28	76.21	74.87
34.27	10.44	88.56		3.90	42.84	6.87	30.27	37.14	18.50	13.91

CUT V2S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	3.21	0.00	45.00	49.00	4.55	2.14	0.00	2.14	100.00	100.00
7.81	4.36	0.09	34.04	39.52	9.76	2.91	0.04	2.94	98.77	98.55
14.01	16.90	0.15	23.72	28.88	17.51	11.27	0.06	11.33	99.47	99.37
14.35	22.45	0.13	15.47	19.59	17.94	14.97	0.05	15.02	99.65	99.59
5.92	12.44	1.06	11.34	13.40	7.40	8.29	0.43	8.72	95.12	94.25
34.27	40.64	81.50		3.90	42.84	27.10	32.75	59.84	45.28	35.54

CUT V2JD1

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	4.64	0.00	45.00	49.00	4.55	2.67	0.00	2.67	100.00	100.00
7.81	5.37	0.07	34.04	39.52	9.76	3.09	0.03	3.12	99.06	98.94
14.01	20.83	0.22	23.72	28.88	17.51	11.97	0.09	12.06	99.23	99.14
14.35	25.06	1.21	15.47	19.59	17.94	14.40	0.51	14.91	96.59	96.17
5.92	15.40	0.99	11.34	13.40	7.40	8.85	0.42	9.26	95.51	94.95
34.27	28.70	98.77		3.90	42.84	16.49	41.49	57.98	28.44	19.56

CUT V2JD2

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	5.47	0.00	45.00	49.00	4.55	3.39	0.00	3.39	100.00	100.00
7.81	6.52	0.00	34.04	39.52	9.76	4.04	0.00	4.04	100.00	100.00
14.01	22.71	0.26	23.72	28.88	17.51	14.07	0.10	14.17	99.30	99.22
14.35	24.93	1.32	15.47	19.59	17.94	15.45	0.50	15.95	96.85	96.49
5.92	13.80	1.43	11.34	13.40	7.40	8.55	0.54	9.09	94.02	93.33
34.27	26.57	96.99		3.90	42.84	16.46	36.89	53.36	30.85	22.85

CUT V2S3

			53.00							
3.64	1.78	0.00	45.00	49.00	4.55	1.47	0.00	1.47	100.00	100.00
7.81	5.71	0.09	34.04	39.52	9.76	4.70	0.04	4.74	99.23	98.60
14.01	14.66	0.09	23.72	28.88	17.51	12.07	0.04	12.11	99.70	99.45
14.35	19.76	0.84	15.47	19.59	17.94	16.27	0.34	16.61	97.95	96.26
5.92	9.66	0.68	11.34	13.40	7.40	7.96	0.28	8.23	96.66	93.90
34.27	48.43	41.90		3.90	42.84	39.89	16.95	56.84	70.18	45.53

CUT V2JD3

			53.00							
3.64	2.70	0.00	45.00	49.00	4.55	2.02	0.00	2.02	100.00	100.00
7.81	4.07	0.00	34.04	39.52	9.76	3.05	0.00	3.05	100.00	100.00
14.01	15.00	0.06	23.72	28.88	17.51	11.23	0.03	11.26	99.77	99.64
14.35	20.85	0.52	15.47	19.59	17.94	15.61	0.23	15.84	98.56	97.79
5.92	10.62	0.59	11.34	13.40	7.40	7.95	0.26	8.21	96.84	95.17
34.27	46.76	55.91		3.90	42.84	35.02	24.60	59.61	58.74	36.94

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PARTICLE SIZE ANALYSIS FOR WATER TEST #12
=========================================
INLET PRESSURE = 207 kPa
SOLIDS = 6%

CUT V2S5
========
  FEED UNDER/  OVER/   SCREEN ARIMEAN    FEED  UNDERFLOW   OVERFLOW     CALC.         Y        Yi
          FLOW   FLOW    SIZE    SIZE  FACTOR     FACTOR     FACTOR      FEED
 (gms)  (gms)  (gms)     (um)    (um)     (%)        (%)        (%)       (%)       (%)       (%)
====================  ===========================================================================
                        53.00
  3.64  21.90   0.16    45.00   49.00    4.55      10.48       0.08     10.56     99.21     99.18
  7.81  20.06   0.50    34.04   39.52    9.76       9.60       0.26      9.86     97.36     97.24
 14.01  32.58   2.07    23.72   28.88   17.51      15.59       1.08     16.67     93.53     93.24
 14.35  17.72  16.79    15.47   19.59   17.94       8.48       8.75     17.24     49.21     46.95
  5.92   1.31  11.35    11.34   13.40    7.40       0.63       5.92      6.54      9.58      5.57
 34.27   6.43  69.13             3.90   42.84       3.08      36.04     39.12      7.87      3.78

CUT V2S7
========
                        53.00
  3.64  19.57   0.20    45.00   49.00    4.55      11.30       0.08     11.38     99.26     99.22
  7.81  18.26   0.64    34.04   39.52    9.76      10.54       0.27     10.81     97.50     97.36
 14.01  29.67   2.14    23.72   28.88   17.51      17.13       0.90     18.04     94.99     94.72
 14.35  22.36  10.01    15.47   19.59   17.94      12.91       4.23     17.14     75.32     74.00
  5.92   3.26  10.33    11.34   13.40    7.40       1.88       4.37      6.25     30.13     26.38
 34.27   6.88  76.68             3.90   42.84       3.97      32.40     36.38     10.92      6.14

CUT V2S4
========
                        53.00
  3.64   6.61   0.06    45.00   49.00    4.55       4.59       0.02      4.61     99.60     99.54
  7.81   9.02   0.03    34.04   39.52    9.76       6.27       0.01      6.28     99.85     99.83
 14.01  23.20   0.57    23.72   28.88   17.51      16.12       0.17     16.29     98.93     98.76
 14.35  23.54   2.23    15.47   19.59   17.94      16.35       0.68     17.03     96.00     95.35
  5.92  10.46   1.71    11.34   13.40    7.40       7.27       0.52      7.79     93.30     92.21
 34.27  27.17  95.40             3.90   42.84      18.87      29.13     48.00     39.32     29.44

CUT V2JD1
=========
                        53.00
  3.64   8.38   0.02    45.00   49.00    4.55       4.80       0.01      4.81     99.82     99.80
  7.81  11.55   0.02    34.04   39.52    9.76       6.62       0.01      6.63     99.87     99.86
 14.01  29.20   0.65    23.72   28.88   17.51      16.73       0.28     17.01     98.37     98.19
 14.35  26.68   2.65    15.47   19.59   17.94      15.29       1.13     16.42     93.11     92.35
  5.92  10.50   4.91    11.34   13.40    7.40       6.02       2.10      8.11     74.16     71.30
 34.27  13.69  91.75             3.90   42.84       7.84      39.18     47.02     16.68      7.47
```

CUT V2JD2

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			53.00							
3.64	7.14	0.05	45.00	49.00	4.55	4.24	0.02	4.26	99.52	99.47
7.81	10.02	0.09	34.04	39.52	9.76	5.95	0.04	5.98	99.39	99.32
14.01	26.69	0.46	23.72	28.88	17.51	15.84	0.19	16.03	98.83	98.70
14.35	26.59	1.91	15.47	19.59	17.94	15.78	0.78	16.56	95.31	94.78
5.92	13.28	2.87	11.34	13.40	7.40	7.88	1.17	9.05	87.11	85.64
34.27	16.28	94.62		3.90	42.84	9.66	38.45	48.12	20.08	10.95

CUT V2S3

			53.00							
3.64	5.14	0.12	45.00	49.00	4.55	4.29	0.03	4.32	99.24	98.70
7.81	7.48	0.07	34.04	39.52	9.76	6.24	0.02	6.26	99.69	99.47
14.01	18.51	0.44	23.72	28.88	17.51	15.44	0.12	15.56	99.23	98.67
14.35	20.94	1.83	15.47	19.59	17.94	17.46	0.50	17.96	97.22	95.21
5.92	8.97	1.47	11.34	13.40	7.40	7.48	0.40	7.88	94.91	91.24
34.27	38.96	56.95		3.90	42.84	32.49	15.53	48.02	67.66	44.30

CUT V2JD3

			53.00							
3.64	5.44	0.02	45.00	49.00	4.55	4.30	0.01	4.30	99.88	99.82
7.81	7.21	0.14	34.04	39.52	9.76	5.70	0.04	5.73	99.39	99.06
14.01	19.84	0.55	23.72	28.88	17.51	15.68	0.14	15.82	99.13	98.66
14.35	22.11	2.27	15.47	19.59	17.94	17.47	0.57	18.04	96.84	95.16
5.92	9.68	1.66	11.34	13.40	7.40	7.65	0.42	8.07	94.83	92.09
34.27	35.72	78.82		3.90	42.84	28.23	19.81	48.04	58.76	36.94

TABLE D-4 PARTITION CURVE DATA FROM THE BENTONITE DRILLING FLUID TESTS

PARTICLE SIZE ANALYSIS FOR MUD TEST #1 INLET PRESSURE = 207 kPa

SOLIDS = 1%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
1.81	2.84	0.00	150.00	165.00	1.81	0.99	0.00	0.99	100.00	100.00
1.15	5.78	0.38	106.00	128.00	1.15	2.01	0.32	2.34	86.12	85.79
5.21	9.90	2.68	75.00	90.50	5.21	3.45	2.29	5.74	60.11	59.15
2.36	2.45	1.92	63.00	69.00	2.36	0.85	1.64	2.49	34.24	32.65
5.28	4.63	7.14	53.00	58.00	5.28	1.61	6.10	7.71	20.92	19.02
6.01	3.16	7.16	45.00	49.00	6.01	1.10	6.12	7.22	15.26	13.22
7.97	2.39	7.24	34.04	39.52	7.97	0.83	6.18	7.02	11.87	9.75
16.04	3.89	24.01	23.72	28.88	16.04	1.36	20.51	21.86	6.20	3.94
19.69	2.22	23.74	15.47	19.59	19.69	0.77	20.28	21.05	3.67	1.36
8.54	0.34	10.71	11.34	13.40	8.54	0.12	9.15	9.27	1.28	-1.10
25.94	4.27	15.02		3.90	25.94	1.49	12.83	14.32	10.39	8.24

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
1.81	2.53	0.00	150.00	165.00	1.81	1.09	0.00	1.09	100.00	100.00
1.15	5.20	0.38	106.00	128.00	1.15	2.24	0.30	2.55	88.08	87.54
5.21	9.12	2.78	75.00	90.50	5.21	3.93	2.22	6.15	63.91	62.27
2.36	3.65	2.05	63.00	69.00	2.36	1.57	1.64	3.21	49.01	46.69
5.28	4.40	7.46	53.00	58.00	5.28	1.90	5.96	7.85	24.15	20.70
6.01	3.80	7.32	45.00	49.00	6.01	1.64	5.85	7.48	21.89	18.34
7.97	2.91	8.23	34.04	39.52	7.97	1.25	6.57	7.83	16.03	12.21
16.04	5.31	26.40	23.72	28.88	16.04	2.29	21.08	23.37	9.80	5.69
19.69	2.99	26.05	15.47	19.59	19.69	1.29	20.80	22.09	5.84	1.55
8.54	0.41	14.82	11.34	13.40	8.54	0.18	11.84	12.01	1.47	-3.01
25.94	6.39	4.51		3.90	25.94	2.76	3.60	6.36	43.34	40.77

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
1.81	2.49	0.00	150.00	165.00	1.81	1.11	0.00	1.11	100.00	100.00
1.15	5.28	0.34	106.00	128.00	1.15	2.34	0.36	2.70	86.72	85.28
5.21	9.55	1.82	75.00	90.50	5.21	4.24	1.92	6.16	68.81	65.42
2.36	3.75	1.39	63.00	69.00	2.36	1.67	1.47	3.13	53.15	48.05
5.28	5.27	4.79	53.00	58.00	5.28	2.34	5.06	7.40	31.63	24.19
6.01	5.31	5.31	45.00	49.00	6.01	2.36	5.61	7.97	29.60	21.95
7.97	4.16	6.78	34.04	39.52	7.97	1.85	7.16	9.01	20.51	11.86
16.04	8.68	18.7	23.72	28.88	16.04	3.85	19.75	23.60	16.33	7.23
19.69	7.14	22.21	15.47	19.59	19.69	3.17	23.45	26.62	11.91	2.33
8.54	2.53	8.56	11.34	13.40	8.54	1.12	9.04	10.16	11.05	1.38
25.94	3.65	0.49		3.90	25.94	1.62	0.52	2.14	75.80	73.17

CUT V1JD1

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
1.81	2.14	0.00	150.00	165.00	1.81	1.02	0.00	1.02	100.00	100.00
1.15	4.32	0.38	106.00	128.00	1.15	2.06	0.42	2.48	82.90	81.82
5.21	8.02	2.02	75.00	90.50	5.21	3.82	2.26	6.07	62.87	60.53
2.36	2.30	1.39	63.00	69.00	2.36	1.10	1.55	2.65	41.38	37.67
5.28	3.95	4.21	53.00	58.00	5.28	1.88	4.70	6.58	28.58	24.07
6.01	3.32	4.76	45.00	49.00	6.01	1.58	5.31	6.90	22.93	18.06
7.97	2.54	7.6	34.04	39.52	7.97	1.21	8.49	9.70	12.48	6.95
16.04	4.89	18.44	23.72	28.88	16.04	2.33	20.59	22.92	10.16	4.49
19.69	3.83	19.42	15.47	19.59	19.69	1.82	21.68	23.51	7.76	1.93
8.54	1.15	8.01	11.34	13.40	8.54	0.55	8.94	9.49	5.77	-0.18
25.94	3.52	6.28		3.90	25.94	1.68	7.01	8.69	19.29	14.20

PARTICLE SIZE ANALYSIS FOR MUD TEST #2

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.52	2.31	0.00	150.00	165.00	0.52	0.26	0.00	0.26	100.00	100.00
0.39	3.86	0.25	106.00	128.00	0.39	0.43	0.23	0.66	64.56	63.51
2.13	7.30	1.54	75.00	90.50	2.13	0.81	1.44	2.25	35.87	33.97
1.44	2.23	1.41	63.00	69.00	1.44	0.25	1.32	1.57	15.73	13.23
3.59	5.21	4.50	53.00	58.00	3.59	0.58	4.21	4.79	12.02	9.41
5.05	4.64	4.97	45.00	49.00	5.05	0.51	4.65	5.16	9.92	7.25
8.55	5.04	7.96	34.04	39.52	8.55	0.56	7.45	8.01	6.95	4.19
16.69	7.38	17.83	23.72	28.88	16.69	0.82	16.69	17.50	4.66	1.83
17.82	6.32	18.1	15.47	19.59	17.82	0.70	16.94	17.64	3.96	1.11
7.74	1.84	7.11	11.34	13.40	7.74	0.20	6.65	6.86	2.96	0.09
36.08	11.82	36.33		3.90	36.08	1.31	34.00	35.31	3.70	0.84

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.52	2.27	0.00	150.00	165.00	0.52	0.26	0.00	0.26	100.00	100.00
0.39	4.69	0.26	106.00	128.00	0.39	0.53	0.23	0.76	69.38	67.77
2.13	9.44	1.47	75.00	90.50	2.13	1.06	1.32	2.38	44.65	41.73
1.44	3.77	1.36	63.00	69.00	1.44	0.42	1.22	1.64	25.83	21.92
3.59	7.42	4.60	53.00	58.00	3.59	0.84	4.13	4.96	16.85	12.46
5.05	7.95	4.93	45.00	49.00	5.05	0.90	4.42	5.32	16.85	12.46
8.55	8.26	8.14	34.04	39.52	8.55	0.93	7.30	8.23	11.31	6.63
16.69	12.55	18.02	23.72	28.88	16.69	1.41	16.16	17.58	8.05	3.20
17.82	9.87	18.42	15.47	19.59	17.82	1.11	16.52	17.64	6.31	1.37
7.74	3.15	7.20	11.34	13.40	7.74	0.35	6.46	6.81	5.21	0.21
36.08	22.03	35.60		3.90	36.08	2.48	31.93	34.42	7.21	2.32

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.52	2.39	0.00	150.00	165.00	0.52	0.27	0.00	0.27	100.00	100.00
0.39	4.76	0.24	106.00	128.00	0.39	0.55	0.20	0.75	73.22	69.97
2.13	11.46	1.43	75.00	90.50	2.13	1.32	1.19	2.51	52.49	46.72
1.44	5.95	1.14	63.00	69.00	1.44	0.68	0.95	1.63	41.84	34.79
3.59	10.79	4.30	53.00	58.00	3.59	1.24	3.58	4.82	25.70	16.69
5.05	12.26	5.10	45.00	49.00	5.05	1.41	4.25	5.65	24.89	15.78
8.55	11.62	7.47	34.04	39.52	8.55	1.33	6.22	7.55	17.66	7.67
16.69	23.1	18.02	23.72	28.88	16.69	2.65	15.01	17.66	15.02	4.71
17.82	18.63	18.63	15.47	19.59	17.82	2.14	15.51	17.65	12.12	1.45
7.74	6.96	7.15	11.34	13.40	7.74	0.80	5.95	6.75	11.83	1.13
36.08	37.82	36.52		3.90	36.08	4.34	30.41	34.75	12.49	1.88

CUT V1JD1

=========

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.52	2.64	0.00	150.00	165.00	0.52	0.30	0.00	0.30	100.00	100.00
0.39	5.20	0.14	106.00	128.00	0.39	0.60	0.12	0.72	82.93	81.73
2.13	12.08	1.43	75.00	90.50	2.13	1.39	1.26	2.65	52.50	49.16
1.44	3.72	1.18	63.00	69.00	1.44	0.43	1.04	1.47	29.20	24.22
3.59	10.53	4.75	53.00	58.00	3.59	1.21	4.19	5.40	22.48	17.03
5.05	9.34	5.38	45.00	49.00	5.05	1.08	4.74	5.82	18.51	12.78
8.55	7.87	5.84	34.04	39.52	8.55	0.91	5.15	6.05	14.99	9.01
16.69	16.68	19.06	23.72	28.88	16.69	1.92	16.80	18.72	10.27	3.96
17.82	13.19	20.12	15.47	19.59	17.82	1.52	17.73	19.25	7.90	1.42
7.74	4.73	8.42	11.34	13.40	7.74	0.55	7.42	7.96	6.85	0.30
36.08	17.07	33.68		3.90	36.08	1.97	29.68	31.65	6.22	-0.38

PARTICLE SIZE ANALYSIS FOR MUD TEST #3 INLET PRESSURE = 207 kPa

SOLIDS = 6%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.27	1.51	0.00	150.00	165.00	0.27	0.10	0.00	0.10	100.00	100.00
0.24	4.11	0.12	106.00	128.00	0.24	0.28	0.11	0.39	71.32	70.61
1.54	13.21	1.05	75.00	90.50	1.54	0.89	0.98	1.87	47.74	46.45
1.27	7.09	1.31	63.00	69.00	1.27	0.48	1.22	1.70	28.21	26.43
3.27	10.69	5.18	53.00	58.00	3.27	0.72	4.83	5.55	13.03	10.88
4.86	10.52	5.82	45.00	49.00	4.86	0.71	5.43	6.14	11.60	9.41
8.65	7.83	5.91	34.04	39.52	8.65	0.53	5.51	6.04	8.78	6.51
16.81	14.88	18.66	23.72	28.88	16.81	1.01	17.40	18.40	5.47	3.13
17.46	9.56	18.87	15.47	19.59	17.46	0.65	17.59	18.24	3.55	1.16
7.59	2.64	7.36	11.34	13.40	7.59	0.18	6.86	7.04	2.54	0.12
38.04	17.96	35.72		3.90	38.04	1.22	33.30	34.52	3.52	1.13

CUT V1S7

			180.00							
0.27	1.15	0.00	150.00	165.00	0.27	0.12	0.00	0.12	100.00	100.00
0.24	3.27	0.10	106.00	128.00	0.24	0.33	0.09	0.42	78.73	77.77
1.54	11.69	1.06	75.00	90.50	1.54	1.19	0.95	2.14	55.53	53.51
1.27	4.16	0.93	63.00	69.00	1.27	0.42	0.84	1.26	33.62	30.61
3.27	11.70	5.06	53.00	58.00	3.27	1.19	4.55	5.74	20.75	17.15
4.86	9.76	4.65	45.00	49.00	4.86	0.99	4.18	5.17	19.20	15.53
8.65	8.11	6.13	34.04	39.52	8.65	0.82	5.51	6.33	13.03	9.08
16.81	15.79	18.46	23.72	28.88	16.81	1.61	16.58	18.19	8.83	4.69
17.46	10.65	18.92	15.47	19.59	17.46	1.08	17.00	18.08	5.99	1.73
7.59	2.89	7.55	11.34	13.40	7.59	0.29	6.78	7.08	4.15	-0.19
38.04	20.83	37.14		3.90	38.04	2.12	33.36	35.48	5.97	1.70

CUT V1S4

			180.00							
0.27	0.78	0.00	150.00	165.00	0.27	0.13	0.00	0.13	100.00	100.00
0.24	2.10	0.10	106.00	128.00	0.24	0.36	0.08	0.44	81.09	79.00
1.54	7.88	0.94	75.00	90.50	1.54	1.34	0.78	2.12	63.13	59.05
1.27	5.32	0.94	63.00	69.00	1.27	0.90	0.78	1.68	53.62	48.48
3.27	8.08	4.46	53.00	58.00	3.27	1.37	3.70	5.07	27.01	18.93
4.86	9.55	4.84	45.00	49.00	4.86	1.62	4.02	5.64	28.72	20.84
8.65	7.63	6.05	34.04	39.52	8.65	1.29	5.02	6.32	20.48	11.69
16.81	16.6	18.19	23.72	28.88	16.81	2.82	15.10	17.92	15.71	6.39
17.46	12.94	18.97	15.47	19.59	17.46	2.19	15.75	17.95	12.23	2.52
7.59	4.39	7.54	11.34	13.40	7.59	0.74	6.26	7.01	10.63	0.74
38.04	24.73	37.97		3.90	38.04	4.19	31.53	35.72	11.74	1.98

CUT V1JD1
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FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.27	0.95	0.00	150.00	165.00	0.27	0.11	0.00	0.11	100.00	100.00
0.24	2.74	0.15	106.00	128.00	0.24	0.31	0.13	0.45	70.32	68.19
1.54	9.79	1.09	75.00	90.50	1.54	1.12	0.96	2.09	53.81	50.50
1.27	4.65	1.08	63.00	69.00	1.27	0.53	0.96	1.49	35.83	31.24
3.27	9.66	4.96	53.00	58.00	3.27	1.11	4.39	5.50	20.16	14.45
4.86	8.75	5.09	45.00	49.00	4.86	1.00	4.51	5.51	18.23	12.38
8.65	7.85	5.82	34.04	39.52	8.65	0.90	5.15	6.05	14.89	8.80
16.81	15.53	18.39	23.72	28.88	16.81	1.78	16.28	18.06	9.87	3.42
17.46	12.11	18.85	15.47	19.59	17.46	1.39	16.69	18.08	7.69	1.08
7.59	4.07	7.46	11.34	13.40	7.59	0.47	6.60	7.07	6.61	-0.08
38.04	23.9	37.11		3.90	38.04	2.74	32.85	35.59	7.71	1.10

PARTICLE SIZE ANALYSIS FOR MUD TEST #4

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.86	0.00	150.00	165.00	0.36	0.15	0.00	0.15	100.00	100.00
0.29	2.79	0.00	106.00	128.00	0.29	0.50	0.00	0.50	100.00	100.00
1.75	11.51	0.11	75.00	90.50	1.75	2.06	0.09	2.15	95.81	95.76
1.33	9.39	0.13	63.00	69.00	1.33	1.68	0.11	1.79	94.04	93.97
3.39	16.17	0.67	53.00	58.00	3.39	2.90	0.55	3.45	84.05	83.86
4.93	21.95	1.33	45.00	49.00	4.93	3.93	1.09	5.03	78.28	78.02
8.62	19.18	6.15	34.04	39.52	8.62	3.44	5.05	8.48	40.51	39.80
16.77	11.81	20.27	23.72	28.88	16.77	2.12	16.64	18.75	11.28	10.23
17.59	2.56	21.48	15.47	19.59	17.59	0.46	17.63	18.09	2.54	1.37
7.64	0.43	9.10	11.34	13.40	7.64	0.08	7.47	7.55	1.02	-0.16
37.33	3.35	40.76		3.90	37.33	0.60	33.46	34.06	1.76	0.59

CUT V1S7

			180.00							
0.36	0.51	0.00	150.00	165.00	0.36	0.13	0.00	0.13	100.00	100.00
0.29	1.61	0.00	106.00	128.00	0.29	0.41	0.00	0.41	100.00	100.00
1.75	6.41	0.13	75.00	90.50	1.75	1.64	0.10	1.74	94.45	94.35
1.33	5.21	0.18	63.00	69.00	1.33	1.34	0.13	1.47	90.90	90.74
3.39	12.00	0.68	53.00	58.00	3.39	3.08	0.51	3.58	85.90	85.64
4.93	17.19	1.02	45.00	49.00	4.93	4.41	0.76	5.17	85.33	85.06
8.62	19.63	3.59	34.04	39.52	8.62	5.04	2.67	7.71	65.37	64.74
16.77	23.65	17.07	23.72	28.88	16.77	6.07	12.69	18.76	32.35	31.12
17.59	5.13	22.73	15.47	19.59	17.59	1.32	16.90	18.21	7.23	5.54
7.64	0.72	10.17	11.34	13.40	7.64	0.18	7.56	7.75	2.39	0.61
37.33	7.94	44.43		3.90	37.33	2.04	33.03	35.07	5.81	4.09

CUT V1S4

			180.00							
0.36	0.29	0.00	150.00	165.00	0.36	0.10	0.00	0.10	100.00	100.00
0.29	1.04	0.00	106.00	128.00	0.29	0.37	0.00	0.37	100.00	100.00
1.75	4.72	0.14	75.00	90.50	1.75	1.68	0.06	1.74	96.53	96.31
1.33	4.39	0.14	63.00	69.00	1.33	1.56	0.06	1.62	96.28	96.04
3.39	8.67	0.82	53.00	58.00	3.39	3.08	0.35	3.43	89.72	89.05
4.93	14.31	1.50	45.00	49.00	4.93	5.08	0.65	5.72	88.73	88.00
8.62	17.78	4.98	34.04	39.52	8.62	6.31	2.14	8.45	74.66	73.02
16.77	24.27	21.42	23.72	28.88	16.77	8.61	9.21	17.83	48.32	44.98
17.59	7.26	28.04	15.47	19.59	17.59	2.58	12.06	14.64	17.60	12.28
7.64	1.18	19.01	11.34	13.40	7.64	0.42	8.18	8.59	4.87	-1.27
37.33	16.09	73.95		3.90	37.33	5.71	31.80	37.51	15.22	9.74

CUT V1JD1

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.48	0.00	150.00	165.00	0.36	0.12	0.00	0.12	100.00	100.00
0.29	1.77	0.00	106.00	128.00	0.29	0.44	0.00	0.44	100.00	100.00
1.75	7.43	0.17	75.00	90.50	1.75	1.85	0.09	1.94	95.62	95.50
1.33	5.05	0.24	63.00	69.00	1.33	1.26	0.12	1.38	91.30	91.08
3.39	15.02	0.82	53.00	58.00	3.39	3.75	0.41	4.16	90.14	89.89
4.93	17.41	1.84	45.00	49.00	4.93	4.35	0.92	5.27	82.52	82.08
8.62	21.89	6.19	34.04	39.52	8.62	5.46	3.10	8.56	63.83	62.91
16.77	19.64	26.61	23.72	28.88	16.77	4.90	13.31	18.21	26.91	25.07
17.59	3.97	29.33	15.47	19.59	17.59	0.99	14.67	15.66	6.33	3.96
7.64	0.63	18.17	11.34	13.40	7.64	0.16	9.09	9.25	1.70	-0.78
37.33	6.71	66.63		3.90	37.33	1.67	33.33	35.01	4.78	2.38

CUT V1S3

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.28	0.00	150.00	165.00	0.36	0.14	0.00	0.14	100.00	100.00
0.29	0.96	0.00	106.00	128.00	0.29	0.48	0.00	0.48	100.00	100.00
1.75	4.29	0.16	75.00	90.50	1.75	2.15	0.05	2.21	97.59	97.02
1.33	2.77	0.20	63.00	69.00	1.33	1.39	0.07	1.46	95.44	94.37
3.39	6.73	0.85	53.00	58.00	3.39	3.38	0.28	3.66	92.29	90.47
4.93	9.85	1.70	45.00	49.00	4.93	4.94	0.56	5.51	89.75	87.34
8.62	15.23	4.85	34.04	39.52	8.62	7.64	1.61	9.25	82.60	78.50
16.77	25.62	17.93	23.72	28.88	16.77	12.86	5.95	18.81	68.35	60.89
17.59	14.42	27.09	15.47	19.59	17.59	7.24	9.00	16.23	44.58	31.53
7.64	3.41	19.33	11.34	13.40	7.64	1.71	6.42	8.13	21.05	2.45
37.33	16.44	77.89		3.90	37.33	8.25	25.86	34.12	24.19	6.32

PARTICLE SIZE ANALYSIS FOR MUD TEST #5

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V2S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.49	0.00	150.00	165.00	0.36	0.16	0.00	0.16	100.00	100.00
0.29	1.48	0.00	106.00	128.00	0.29	0.47	0.00	0.47	100.00	100.00
1.75	6.03	0.18	75.00	90.50	1.75	1.92	0.08	2.00	95.92	95.80
1.33	4.24	0.21	63.00	69.00	1.33	1.35	0.10	1.45	93.41	93.21
3.39	10.32	0.78	53.00	58.00	3.39	3.29	0.35	3.64	90.28	89.99
4.93	15.01	1.61	45.00	49.00	4.93	4.78	0.73	5.51	86.74	86.35
8.62	11.83	2.89	34.04	39.52	8.62	3.77	1.31	5.08	74.18	73.41
16.77	29.72	19.75	23.72	28.88	16.77	9.47	8.97	18.44	51.36	49.92
17.59	11.09	28.33	15.47	19.59	17.59	3.53	12.87	16.40	21.55	19.23
7.64	1.82	20.23	11.34	13.40	7.64	0.58	9.19	9.77	5.94	3.16
37.33	7.97	76.02		3.90	37.33	2.54	34.53	37.07	6.85	4.10

CUT V2S7

			180.00							
0.36	0.26	0.00	150.00	165.00	0.36	0.10	0.00	0.10	100.00	100.00
0.29	1.19	0.00	106.00	128.00	0.29	0.45	0.00	0.45	100.00	100.00
1.75	5.30	0.22	75.00	90.50	1.75	1.99	0.09	2.08	95.60	95.24
1.33	3.10	0.25	63.00	69.00	1.33	1.16	0.10	1.27	91.79	91.12
3.39	9.18	1.07	53.00	58.00	3.39	3.45	0.45	3.89	88.55	87.63
4.93	13.18	1.64	45.00	49.00	4.93	4.95	0.68	5.63	87.87	86.89
8.62	15.88	3.27	34.04	39.52	8.62	5.96	1.36	7.32	81.40	79.90
16.77	25.84	18.94	23.72	28.88	16.77	9.70	7.89	17.59	55.15	51.54
17.59	11.50	27.69	15.47	19.59	17.59	4.32	11.53	15.85	27.23	21.38
7.64	2.55	19.72	11.34	13.40	7.64	0.96	8.21	9.17	10.44	3.23
37.33	12.02	77.20		3.90	37.33	4.51	32.15	36.66	12.30	5.25

CUT V2S4

			180.00							
0.36	0.22	0.00	150.00	165.00	0.36	0.11	0.00	0.11	100.00	100.00
0.29	0.82	0.00	106.00	128.00	0.29	0.41	0.00	0.41	100.00	100.00
1.75	3.34	0.23	75.00	90.50	1.75	1.66	0.08	1.73	95.54	94.46
1.33	2.81	0.19	63.00	69.00	1.33	1.39	0.06	1.46	95.62	94.55
3.39	6.46	1.01	53.00	58.00	3.39	3.20	0.34	3.54	90.41	88.09
4.93	9.18	1.54	45.00	49.00	4.93	4.55	0.52	5.07	89.78	87.31
8.62	9.73	2.61	34.04	39.52	8.62	4.82	0.88	5.70	84.61	80.88
16.77	26.72	14.71	23.72	28.88	16.77	13.25	4.95	18.19	72.81	66.23
17.59	16.84	27.1	15.47	19.59	17.59	8.35	9.11	17.46	47.81	35.18
7.64	4.46	18.61	11.34	13.40	7.64	2.21	6.26	8.47	26.11	8.22
37.33	19.42	84.00		3.90	37.33	9.63	28.24	37.87	25.42	7.37

CUT V3S5
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FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.51	0.00	150.00	165.00	0.36	0.13	0.00	0.13	100.00	100.00
0.29	1.83	0.00	106.00	128.00	0.29	0.47	0.00	0.47	100.00	100.00
1.75	8.54	0.16	75.00	90.50	1.75	2.19	0.07	2.26	96.88	96.46
1.33	5.73	0.11	63.00	69.00	1.33	1.47	0.05	1.52	96.80	96.37
3.39	13.56	0.83	53.00	58.00	3.39	3.47	0.37	3.84	90.48	89.19
4.93	15.77	1.90	45.00	49.00	4.93	4.04	0.84	4.88	82.84	80.51
8.62	14.44	6.78	34.04	39.52	8.62	3.70	2.99	6.69	55.33	49.27
16.77	29.19	26.00	23.72	28.88	16.77	7.48	11.45	18.93	39.50	31.29
17.59	16.76	27.91	15.47	19.59	17.59	4.29	12.29	16.59	25.88	15.83
7.64	4.16	18.43	11.34	13.40	7.64	1.07	8.12	9.18	11.60	-0.39
37.33	21.96	67.88		3.90	37.33	5.63	29.90	35.52	15.84	4.41

CUT V3S7
========

			180.00							
0.36	0.20	0.00	150.00	165.00	0.36	0.09	0.00	0.09	100.00	100.00
0.29	0.73	0.00	106.00	128.00	0.29	0.34	0.00	0.34	100.00	100.00
1.75	3.20	0.16	75.00	90.50	1.75	1.50	0.06	1.56	96.36	95.25
1.33	2.70	0.19	63.00	69.00	1.33	1.27	0.07	1.33	94.96	93.42
3.39	6.42	0.86	53.00	58.00	3.39	3.01	0.30	3.32	90.82	88.02
4.93	9.06	1.61	45.00	49.00	4.93	4.25	0.57	4.82	88.18	84.57
8.62	10.58	3.32	34.04	39.52	8.62	4.96	1.18	6.14	80.86	75.01
16.77	23.21	21.05	23.72	28.88	16.77	10.89	7.45	18.34	59.37	46.96
17.59	15.31	27.84	15.47	19.59	17.59	7.18	9.85	17.04	42.16	24.49
7.64	4.44	19.13	11.34	13.40	7.64	2.08	6.77	8.85	23.53	0.16
37.33	24.15	75.84		3.90	37.33	11.33	26.84	38.17	29.68	8.20

PARTICLE SIZE ANALYSIS FOR MUD TEST #6

INLET PRESSURE = 276 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.68	0.00	150.00	165.00	0.36	0.15	0.00	0.15	100.00	100.00
0.29	1.97	0.00	106.00	128.00	0.29	0.45	0.00	0.45	100.00	100.00
1.75	9.05	0.06	75.00	90.50	1.75	2.05	0.04	2.09	98.22	98.21
1.33	7.20	0.05	63.00	69.00	1.33	1.63	0.03	1.66	98.14	98.12
3.39	13.90	0.49	53.00	58.00	3.39	3.15	0.30	3.45	91.22	91.15
4.93	18.90	1.27	45.00	49.00	4.93	4.28	0.79	5.07	84.50	84.37
8.62	24.84	7.06	34.04	39.52	8.62	5.63	4.37	10.00	56.32	55.94
16.77	13.44	25.33	23.72	28.86	16.77	3.05	15.67	18.72	16.28	15.54
17.59	2.58	24.83	15.47	19.59	17.59	0.58	15.36	15.95	3.67	2.82
7.64	0.4	7.45	11.34	13.40	7.64	0.09	4.61	4.70	1.93	1.07
37.33	7.04	58.46		3.90	37.33	1.60	36.17	37.76	4.23	3.39

CUT V1S7

			180.00							
0.36	0.64	0.00	150.00	165.00	0.36	0.17	0.00	0.17	100.00	100.00
0.29	1.68	0.00	106.00	128.00	0.29	0.45	0.00	0.45	100.00	100.00
1.75	6.59	0.06	75.00	90.50	1.75	1.77	0.04	1.81	98.06	98.03
1.33	5.87	0.06	63.00	69.00	1.33	1.58	0.04	1.62	97.83	97.80
3.39	12.55	0.44	53.00	58.00	3.39	3.38	0.26	3.64	92.93	92.83
4.93	15.74	0.77	45.00	49.00	4.93	4.24	0.45	4.69	90.40	90.26
8.62	25.86	4.13	34.04	39.52	8.62	6.96	2.41	9.38	74.26	73.89
16.77	19.31	22.94	23.72	28.88	16.77	5.20	13.41	18.61	27.94	26.91
17.59	3.68	26.36	15.47	19.59	17.59	0.99	15.41	16.40	6.04	4.70
7.64	0.57	15.04	11.34	13.40	7.64	0.15	8.79	8.95	1.72	0.31
37.33	7.51	55.20		3.90	37.33	2.02	32.27	34.29	5.90	4.55

CUT V1S4

			180.00							
0.36	0.46	0.00	150.00	165.00	0.36	0.17	0.00	0.17	100.00	100.00
0.29	1.25	0.00	106.00	128.00	0.29	0.47	0.00	0.47	100.00	100.00
1.75	5.19	0.09	75.00	90.50	1.75	1.95	0.04	1.99	97.74	97.66
1.33	3.62	0.07	63.00	69.00	1.33	1.36	0.03	1.39	97.49	97.40
3.39	9.81	0.47	53.00	58.00	3.39	3.68	0.23	3.92	94.00	93.78
4.93	13.13	0.90	45.00	49.00	4.93	4.93	0.45	5.38	91.64	91.32
8.62	21.65	3.24	34.04	39.52	8.62	8.13	1.62	9.74	83.38	82.76
16.77	25.46	17.91	23.72	28.88	16.77	9.56	8.95	18.51	51.63	49.82
17.59	7.4	25.68	15.47	19.59	17.59	2.78	12.83	15.61	17.79	14.70
7.64	1.07	13.49	11.34	13.40	7.64	0.40	6.74	7.14	5.62	2.08
37.33	10.96	63.15		3.90	37.33	4.11	31.56	35.67	11.53	8.21

CUT V1S3

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.23	0.00	150.00	165.00	0.36	0.12	0.00	0.12	100.00	100.00
0.29	0.80	0.00	106.00	128.00	0.29	0.42	0.00	0.42	100.00	100.00
1.75	3.36	0.09	75.00	90.50	1.75	1.77	0.03	1.80	98.11	97.72
1.33	2.56	0.08	63.00	69.00	1.33	1.35	0.03	1.38	97.80	97.35
3.39	6.68	0.49	53.00	58.00	3.39	3.52	0.19	3.70	94.98	93.95
4.93	9.73	0.86	45.00	49.00	4.93	5.12	0.33	5.45	94.02	92.78
8.62	17.42	3.01	34.04	39.52	8.62	9.17	1.14	10.31	88.94	86.66
16.77	26.45	13.97	23.72	28.88	16.77	13.92	5.29	19.21	72.45	66.77
17.59	12.04	25.13	15.47	19.59	17.59	6.34	9.52	15.86	39.95	27.59
7.64	1.73	15.88	11.34	13.40	7.64	0.91	6.02	6.93	13.14	-4.75
37.33	19.00	65.49		3.90	37.33	10.00	24.82	34.82	28.72	14.04

PARTICLE SIZE ANALYSIS FOR MUD TEST #7
INLET PRESSURE = 276 kPa
SOLIDS = 3%

CUT V2S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.45	0.00	150.00	165.00	0.36	0.18	0.00	0.18	100.00	100.00
0.29	1.25	0.00	106.00	128.00	0.29	0.49	0.00	0.49	100.00	100.00
1.75	5.25	0.02	75.00	90.50	1.75	2.04	0.01	2.05	99.52	99.51
1.33	4.88	0.05	63.00	69.00	1.33	1.90	0.02	1.92	98.73	98.70
3.39	8.61	0.26	53.00	58.00	3.39	3.35	0.13	3.48	96.35	96.27
4.93	12.58	0.54	45.00	49.00	4.93	4.90	0.26	5.16	94.89	94.77
8.62	21.56	1.70	34.04	39.52	8.62	8.39	0.83	9.22	90.99	90.79
16.77	30.46	14.61	23.72	28.88	16.77	11.86	7.14	18.99	62.41	61.58
17.59	8.12	26.16	15.47	19.59	17.59	3.16	12.78	15.94	19.82	18.04
7.64	0.93	17.23	11.34	13.40	7.64	0.36	8.42	8.78	4.12	2.00
37.33	5.91	64.43		3.90	37.33	2.30	31.48	33.78	6.81	4.74

CUT V2S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.37	0.00	150.00	165.00	0.36	0.17	0.00	0.17	100.00	100.00
0.29	1.19	0.00	106.00	128.00	0.29	0.53	0.00	0.53	100.00	100.00
1.75	4.69	0.02	75.00	90.50	1.75	2.10	0.01	2.10	99.58	99.55
1.33	3.49	0.03	63.00	69.00	1.33	1.56	0.01	1.57	99.16	99.10
3.39	8.31	0.33	53.00	58.00	3.39	3.71	0.15	3.86	96.21	95.98
4.93	11.60	0.57	45.00	49.00	4.93	5.18	0.25	5.43	95.36	95.07
8.62	17.93	1.80	34.04	39.52	8.62	8.01	0.80	8.81	90.95	90.40
16.77	28.08	13.77	23.72	28.88	16.77	12.54	6.10	18.64	67.30	65.30
17.59	10.52	25.71	15.47	19.59	17.59	4.70	11.38	16.08	29.23	24.91
7.64	1.74	16.38	11.34	13.40	7.64	0.78	7.25	8.03	9.68	4.17
37.33	12.08	66.39		3.90	37.33	5.40	29.39	34.78	15.51	10.36

CUT V2S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.36	0.26	0.00	150.00	165.00	0.36	0.15	0.00	0.15	100.00	100.00
0.29	0.75	0.00	106.00	128.00	0.29	0.42	0.00	0.42	100.00	100.00
1.75	3.02	0.05	75.00	90.50	1.75	1.69	0.02	1.70	98.96	98.75
1.33	2.85	0.08	63.00	69.00	1.33	1.59	0.03	1.62	98.26	97.89
3.39	5.81	0.46	53.00	58.00	3.39	3.25	0.16	3.41	95.23	94.23
4.93	9.83	0.76	45.00	49.00	4.93	5.49	0.27	5.76	95.34	94.36
8.62	14.38	2.21	34.04	39.52	8.62	8.03	0.78	8.81	91.15	89.28
16.77	27.12	10.72	23.72	28.88	16.77	15.15	3.79	18.93	80.01	75.80
17.59	13.85	25.16	15.47	19.59	17.59	7.74	8.88	16.62	46.55	35.30
7.64	2.28	16.78	11.34	13.40	7.64	1.27	5.93	7.20	17.69	0.38
37.33	19.85	68.78		3.90	37.33	11.09	24.29	35.38	31.34	16.90

PARTICLE SIZE ANALYSIS FOR MUD TEST #8

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.02	0.03	0.00	150.00	165.00	0.02	0.01	0.00	0.01	100.00	100.00
0.09	0.21	0.00	106.00	128.00	0.09	0.09	0.00	0.09	100.00	100.00
0.93	2.19	0.03	75.00	90.50	0.93	0.98	0.01	0.99	98.66	98.64
1.09	2.80	0.03	63.00	69.00	1.09	1.25	0.01	1.27	98.95	98.94
2.94	6.83	0.07	53.00	58.00	2.94	3.06	0.03	3.09	99.00	98.98
4.67	11.64	0.18	45.00	49.00	4.67	5.21	0.08	5.29	98.49	98.47
8.77	17.64	0.42	34.04	39.52	8.77	7.89	0.19	8.08	97.70	97.66
16.94	33.75	2.6	23.72	28.88	16.94	15.10	1.15	16.25	92.93	92.81
17.09	18.19	20.63	15.47	19.59	17.09	8.14	9.12	17.26	47.16	46.30
7.43	0.99	15.56	11.34	13.40	7.43	0.44	6.88	7.32	6.05	4.52
40.03	5.73	85.48		3.90	40.03	2.56	37.79	40.35	6.35	4.83

CUT V1S7

			180.00							
0.02	0.03	0.00	150.00	165.00	0.02	0.02	0.00	0.02	100.00	100.00
0.09	0.16	0.00	106.00	128.00	0.09	0.09	0.00	0.09	100.00	100.00
0.93	1.81	0.03	75.00	90.50	0.93	0.99	0.01	1.00	98.90	98.88
1.09	2.02	0.03	63.00	69.00	1.09	1.10	0.01	1.11	99.02	99.00
2.94	5.52	0.08	53.00	58.00	2.94	3.01	0.03	3.04	99.04	99.02
4.67	8.37	0.16	45.00	49.00	4.67	4.56	0.06	4.62	98.74	98.71
8.77	15.79	0.38	34.04	39.52	8.77	8.60	0.14	8.74	98.42	98.38
16.94	31.25	1.71	23.72	28.88	16.94	17.02	0.62	17.64	96.47	96.40
17.09	25.40	9.30	15.47	19.59	17.09	13.84	3.39	17.22	80.33	79.93
7.43	3.91	13.62	11.34	13.40	7.43	2.13	4.96	7.09	30.04	28.59
40.03	5.74	99.69		3.90	40.03	3.13	36.31	39.44	7.93	6.03

CUT V1S4

			180.00							
0.02	0.04	0.00	150.00	165.00	0.02	0.02	0.00	0.02	100.00	100.00
0.09	0.13	0.00	106.00	128.00	0.09	0.08	0.00	0.08	100.00	100.00
0.93	1.29	0.07	75.00	90.50	0.93	0.78	0.02	0.80	97.20	97.12
1.09	1.44	0.07	63.00	69.00	1.09	0.87	0.02	0.89	97.49	97.41
2.94	4.42	0.08	53.00	58.00	2.94	2.66	0.03	2.68	99.05	99.02
4.67	6.72	0.20	45.00	49.00	4.67	4.04	0.06	4.11	98.45	98.40
8.77	15.52	0.49	34.04	39.52	8.77	9.33	0.16	9.49	98.35	98.30
16.94	27.09	2.02	23.72	28.88	16.94	16.29	0.64	16.94	96.20	96.08
17.09	24.92	5.62	15.47	19.59	17.09	14.99	1.79	16.78	89.32	89.00
7.43	9.93	5.96	11.34	13.40	7.43	5.97	1.90	7.87	75.86	75.13
40.03	8.50	110.49		3.90	40.03	5.11	35.23	40.34	12.67	10.03

PARTICLE SIZE ANALYSIS FOR MUD TEST #9 INLET PRESSURE = 207 kpa

SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.09	0.09	0.00	150.00	165.00	0.09	0.04	0.00	0.04	100.00	100.00
0.13	0.45	0.00	106.00	128.00	0.13	0.19	0.00	0.19	100.00	100.00
1.09	3.24	0.03	75.00	90.50	1.09	1.37	0.01	1.38	99.00	98.98
1.14	1.70	0.03	63.00	69.00	1.14	0.72	0.01	0.73	98.11	98.08
3.03	9.00	0.11	53.00	58.00	3.03	3.81	0.05	3.86	98.68	98.66
4.72	12.62	0.16	45.00	49.00	4.72	5.34	0.07	5.41	98.64	98.61
8.74	19.00	0.39	34.04	39.52	8.74	8.04	0.18	8.22	97.81	97.77
16.91	34.67	2.70	23.72	28.88	16.91	14.67	1.25	15.91	92.17	92.02
17.19	13.67	17.34	15.47	19.59	17.19	5.78	8.00	13.79	41.95	40.87
7.47	0.72	7.67	11.34	13.40	7.47	0.30	3.54	3.84	7.92	6.21
39.49	4.84	96.57		3.90	39.49	2.05	44.57	46.62	4.39	2.61

CUT V1S7

			180.00							
0.09	0.06	0.00	150.00	165.00	0.09	0.03	0.00	0.03	100.00	100.00
0.13	0.25	0.00	106.00	128.00	0.13	0.13	0.00	0.13	100.00	100.00
1.09	1.90	0.03	75.00	90.50	1.09	0.97	0.01	0.98	98.81	98.78
1.14	2.55	0.03	63.00	69.00	1.14	1.30	0.01	1.32	99.11	99.09
3.03	5.75	0.15	53.00	58.00	3.03	2.94	0.06	3.00	98.04	98.01
4.72	9.61	0.17	45.00	49.00	4.72	4.91	0.07	4.98	98.67	98.64
8.74	16.80	0.56	34.04	39.52	8.74	8.59	0.22	8.81	97.51	97.47
16.91	32.73	1.83	23.72	28.88	16.91	16.73	0.72	17.45	95.90	95.82
17.19	22.74	10.04	15.47	19.59	17.19	11.63	3.93	15.55	74.76	74.28
7.47	1.93	6.31	11.34	13.40	7.47	0.99	2.47	3.45	28.57	27.22
39.49	5.68	105.88		3.90	39.49	2.90	41.39	44.30	6.56	4.78

CUT V1S4

			180.00							
0.09	0.04	0.00	150.00	165.00	0.09	0.02	0.00	0.02	100.00	100.00
0.13	0.25	0.00	106.00	128.00	0.13	0.15	0.00	0.15	100.00	100.00
1.09	1.65	0.02	75.00	90.50	1.09	0.97	0.01	0.97	99.32	99.29
1.14	1.66	0.02	63.00	69.00	1.14	0.97	0.01	0.98	99.32	99.30
3.03	5.38	0.11	53.00	58.00	3.03	3.15	0.04	3.19	98.85	98.82
4.72	8.63	0.13	45.00	49.00	4.72	5.05	0.04	5.10	99.15	99.12
8.74	14.00	0.44	34.04	39.52	8.74	8.20	0.15	8.34	98.25	98.19
16.91	28.44	1.53	23.72	28.88	16.91	16.65	0.51	17.16	97.04	96.94
17.19	24.20	3.38	15.47	19.59	17.19	14.17	1.12	15.29	92.67	92.42
7.47	7.07	2.95	11.34	13.40	7.47	4.14	0.98	5.12	80.88	80.22
39.49	8.68	116.42		3.90	39.49	5.08	38.61	43.70	11.63	8.59

PARTICLE SIZE ANALYSIS FOR MUD TEST #10

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.16	0.20	0.00	150.00	165.00	0.16	0.08	0.00	0.08	100.00	100.00
0.17	0.72	0.00	106.00	128.00	0.17	0.27	0.00	0.27	100.00	100.00
1.26	3.95	0.05	75.00	90.50	1.26	1.51	0.02	1.53	98.39	98.36
1.19	3.95	0.03	63.00	69.00	1.19	1.51	0.01	1.52	99.02	99.01
3.12	9.68	0.13	53.00	58.00	3.12	3.69	0.06	3.76	98.29	98.26
4.77	14.65	0.28	45.00	49.00	4.77	5.59	0.14	5.73	97.58	97.54
8.71	21.59	0.89	34.04	39.52	8.71	8.24	0.44	8.68	94.93	94.84
16.87	33.15	7.6	23.72	28.88	16.87	12.65	3.76	16.41	77.09	76.71
17.29	6.92	23.57	15.47	19.59	17.29	2.64	11.66	14.30	18.46	17.11
7.51	0.55	7.28	11.34	13.40	7.51	0.21	3.60	3.81	5.51	3.94
38.95	4.64	85.17		3.90	38.95	1.77	42.14	43.91	4.03	2.44

CUT V1S7

			180.00							
0.16	0.16	0.00	150.00	165.00	0.16	0.07	0.00	0.07	100.00	100.00
0.17	0.55	0.00	106.00	128.00	0.17	0.26	0.00	0.26	100.00	100.00
1.26	3.48	0.01	75.00	90.50	1.26	1.62	0.00	1.62	99.74	99.73
1.19	3.20	0.02	63.00	69.00	1.19	1.49	0.01	1.49	99.43	99.41
3.12	8.16	0.14	53.00	58.00	3.12	3.79	0.06	3.85	98.44	98.40
4.77	12.10	0.21	45.00	49.00	4.77	5.62	0.09	5.71	98.42	98.39
8.71	19.13	0.55	34.04	39.52	8.71	8.88	0.24	9.12	97.41	97.35
16.87	31.39	1.96	23.72	28.88	16.87	14.57	0.84	15.41	94.55	94.42
17.29	14.17	9.25	15.47	19.59	17.29	6.58	3.96	10.54	62.40	61.50
7.51	0.96	3.64	11.34	13.40	7.51	0.45	1.56	2.01	22.22	20.37
38.95	6.70	109.22		3.90	38.95	3.11	46.81	49.92	6.23	3.99

CUT V1S4

			180.00							
0.16	0.12	0.00	150.00	165.00	0.16	0.07	0.00	0.07	100.00	100.00
0.17	0.56	0.00	106.00	128.00	0.17	0.31	0.00	0.31	100.00	100.00
1.26	3.11	0.04	75.00	90.50	1.26	1.71	0.01	1.72	99.16	99.13
1.19	3.27	0.04	63.00	69.00	1.19	1.80	0.01	1.81	99.20	99.17
3.12	5.87	0.14	53.00	58.00	3.12	3.22	0.05	3.27	98.46	98.40
4.77	8.81	0.30	45.00	49.00	4.77	4.84	0.11	4.95	97.81	97.73
8.71	16.34	0.73	34.04	39.52	8.71	8.97	0.26	9.24	97.15	97.05
16.87	28.8	3.06	23.72	28.88	16.87	15.81	1.10	16.92	93.48	93.24
17.29	20.21	12.37	15.47	19.59	17.29	11.10	4.46	15.56	71.32	70.29
7.51	2.70	11.19	11.34	13.40	7.51	1.48	4.04	5.52	26.86	24.23
38.95	10.21	97.13		3.90	38.95	5.61	35.04	40.64	13.79	10.70

PARTICLE SIZE ANALYSIS FOR MUD TEST #11

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.23	0.26	0.00	150.00	165.00	0.23	0.08	0.00	0.08	100.00	100.00
0.21	1.04	0.00	106.00	128.00	0.21	0.33	0.00	0.33	100.00	100.00
1.42	4.94	0.01	75.00	90.50	1.42	1.56	0.01	1.57	99.65	99.65
1.24	4.70	0.02	63.00	69.00	1.24	1.49	0.01	1.50	99.27	99.26
3.21	11.25	0.13	53.00	58.00	3.21	3.56	0.07	3.64	98.05	98.02
4.83	18.28	0.27	45.00	49.00	4.83	5.79	0.15	5.94	97.52	97.48
8.68	25.85	1.66	34.04	39.52	8.68	8.19	0.91	9.10	90.03	89.89
16.84	25.27	12.32	23.72	28.88	16.84	8.01	6.73	14.74	54.31	53.71
17.39	3.56	15.71	15.47	19.59	17.39	1.13	8.59	9.71	11.61	10.45
7.56	0.4	3.15	11.34	13.40	7.56	0.13	1.72	1.85	6.86	5.63
38.39	4.45	91.73		3.90	38.39	1.41	50.14	51.55	2.73	1.45

CUT V1S7

			180.00							
0.23	0.29	0.00	150.00	165.00	0.23	0.12	0.00	0.12	100.00	100.00
0.21	0.90	0.00	106.00	128.00	0.21	0.37	0.00	0.37	100.00	100.00
1.42	4.61	0.02	75.00	90.50	1.42	1.88	0.01	1.89	99.50	99.49
1.24	3.42	0.04	63.00	69.00	1.24	1.39	0.02	1.41	98.66	98.64
3.21	9.47	0.14	53.00	58.00	3.21	3.86	0.07	3.93	98.31	98.28
4.83	14.78	0.38	45.00	49.00	4.83	6.02	0.18	6.20	97.10	97.05
8.68	22.51	1.41	34.04	39.52	8.68	9.18	0.67	9.84	93.21	93.10
16.84	30.00	7.69	23.72	28.88	16.84	12.23	3.64	15.87	77.04	76.67
17.39	6.59	17.98	15.47	19.59	17.39	2.69	8.52	11.21	23.97	22.75
7.56	0.54	5.05	11.34	13.40	7.56	0.22	2.39	2.61	8.42	6.96
38.39	6.89	92.29		3.90	38.39	2.81	43.74	46.55	6.03	4.53

CUT V1S4

			180.00							
0.23	0.20	0.00	150.00	165.00	0.23	0.10	0.00	0.10	100.00	100.00
0.21	0.56	0.00	106.00	128.00	0.21	0.28	0.00	0.28	100.00	100.00
1.42	3.15	0.02	75.00	90.50	1.42	1.56	0.01	1.57	99.49	99.46
1.24	2.71	0.02	63.00	69.00	1.24	1.34	0.01	1.35	99.40	99.37
3.21	6.50	0.10	53.00	58.00	3.21	3.22	0.04	3.26	98.76	98.70
4.83	10.03	0.22	45.00	49.00	4.83	4.97	0.09	5.06	98.24	98.16
8.68	21.43	0.78	34.04	39.52	8.68	10.62	0.31	10.93	97.12	96.98
16.84	31.19	2.61	23.72	28.88	16.84	15.45	1.05	16.51	93.62	93.32
17.39	15.62	6.03	15.47	19.59	17.39	7.74	2.43	10.17	76.07	74.95
7.56	1.65	1.63	11.34	13.40	7.56	0.82	0.66	1.48	55.40	53.32
38.39	6.96	113.59		3.90	38.39	3.45	45.85	49.30	6.99	2.64

PARTICLE SIZE ANALYSIS FOR MUD TEST #12
INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.29	0.60	0.00	150.00	165.00	0.29	0.17	0.00	0.17	100.00	100.00
0.25	1.72	0.00	106.00	128.00	0.25	0.49	0.00	0.49	100.00	100.00
1.59	7.52	0.09	75.00	90.50	1.59	2.15	0.05	2.20	97.67	97.64
1.28	6.10	0.07	63.00	69.00	1.28	1.75	0.04	1.79	97.76	97.73
3.30	12.09	0.51	53.00	58.00	3.30	3.46	0.29	3.75	92.24	92.14
4.88	18.42	1.03	45.00	49.00	4.88	5.27	0.59	5.86	89.97	89.84
8.65	29.43	5.25	34.04	39.52	8.65	8.43	3.00	11.42	73.76	73.41
16.80	16.59	22.18	23.72	28.88	16.80	4.75	12.66	17.41	27.28	26.32
17.49	2.46	17.47	15.47	19.59	17.49	0.70	9.97	10.68	6.60	5.36
7.60	0.36	2.74	11.34	13.40	7.60	0.10	1.56	1.67	6.18	4.95
37.87	4.71	75.66		3.90	37.87	1.35	43.20	44.55	3.03	1.75

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.29	0.45	0.00	150.00	165.00	0.29	0.16	0.00	0.16	100.00	100.00
0.25	1.20	0.00	106.00	128.00	0.25	0.43	0.00	0.43	100.00	100.00
1.59	5.08	0.08	75.00	90.50	1.59	1.83	0.04	1.87	97.81	97.76
1.28	4.36	0.08	63.00	69.00	1.28	1.57	0.04	1.61	97.45	97.40
3.30	9.11	0.52	53.00	58.00	3.30	3.28	0.27	3.54	92.48	92.33
4.88	14.84	1.07	45.00	49.00	4.88	5.34	0.55	5.89	90.69	90.49
8.65	26.08	3.52	34.04	39.52	8.65	9.38	1.80	11.18	83.88	83.54
16.80	27.38	17.64	23.72	28.88	16.80	9.85	9.04	18.88	52.15	51.16
17.49	5.09	24.22	15.47	19.59	17.49	1.83	12.41	14.24	12.86	11.04
7.60	0.69	7.44	11.34	13.40	7.60	0.25	3.81	4.06	6.11	4.16
37.87	5.72	70.43		3.90	37.87	2.06	36.08	38.13	5.40	3.43

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.29	0.30	0.00	150.00	165.00	0.29	0.13	0.00	0.13	100.00	100.00
0.25	1.12	0.00	106.00	128.00	0.25	0.50	0.00	0.50	100.00	100.00
1.59	4.75	0.08	75.00	90.50	1.59	2.12	0.04	2.15	98.35	98.26
1.28	3.77	0.08	63.00	69.00	1.28	1.68	0.04	1.72	97.93	97.82
3.30	8.76	0.45	53.00	58.00	3.30	3.91	0.20	4.11	95.14	94.87
4.88	14.74	0.96	45.00	49.00	4.88	6.57	0.43	7.00	93.92	93.58
8.65	19.27	3.23	34.04	39.52	8.65	8.59	1.43	10.02	85.72	84.92
16.80	28.25	11.9	23.72	28.88	16.80	12.60	5.28	17.87	70.48	68.83
17.49	9.88	24.17	15.47	19.59	17.49	4.41	10.71	15.12	29.14	25.17
7.60	1.10	14.59	11.34	13.40	7.60	0.49	6.47	6.96	7.05	1.85
37.87	8.06	69.54		3.90	37.87	3.59	30.83	34.42	10.44	5.43

PARTICLE SIZE ANALYSIS FOR MUD TEST #13 INLET PRESSURE = 207 kPa

SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.45	1.45	0.00	150.00	165.00	0.45	0.25	0.00	0.25	100.00	100.00
0.34	3.76	0.00	106.00	128.00	0.34	0.65	0.00	0.65	100.00	100.00
1.96	12.24	0.28	75.00	90.50	1.96	2.10	0.19	2.29	91.88	91.78
1.39	10.64	0.38	63.00	69.00	1.39	1.83	0.25	2.08	87.88	87.72
3.50	16.29	1.62	53.00	58.00	3.50	2.80	1.07	3.87	72.25	71.89
4.99	19.55	3.36	45.00	49.00	4.99	3.35	2.23	5.58	60.11	59.59
8.58	18.48	11.91	34.04	39.52	8.58	3.17	7.89	11.06	28.66	27.74
16.73	8.86	26.13	23.72	28.88	16.73	1.52	17.32	18.84	8.07	6.88
17.71	2.25	24.71	15.47	19.59	17.71	0.39	16.38	16.76	2.30	1.04
7.70	0.36	12.11	11.34	13.40	7.70	0.06	8.03	8.09	0.76	-0.52
36.65	6.12	44.5		3.90	36.65	1.05	29.49	30.54	3.44	2.19

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.45	1.12	0.00	150.00	165.00	0.45	0.24	0.00	0.24	100.00	100.00
0.34	2.84	0.00	106.00	128.00	0.34	0.60	0.00	0.60	100.00	100.00
1.96	9.54	0.03	75.00	90.50	1.96	2.02	0.02	2.04	99.07	99.05
1.39	7.70	0.03	63.00	69.00	1.39	1.63	0.02	1.65	98.85	98.82
3.50	13.77	1.64	53.00	58.00	3.50	2.92	1.03	3.95	73.85	73.16
4.99	17.03	3.23	45.00	49.00	4.99	3.61	2.04	5.65	63.94	63.00
8.58	18.80	10.56	34.04	39.52	8.58	3.99	6.66	10.64	37.45	35.81
16.73	12.20	25.33	23.72	28.88	16.73	2.59	15.97	18.55	13.94	11.69
17.71	3.30	24.94	15.47	19.59	17.71	0.70	15.72	16.42	4.26	1.75
7.70	0.54	12.80	11.34	13.40	7.70	0.11	8.07	8.18	1.40	-1.18
36.65	13.16	46.44		3.90	36.65	2.79	29.28	32.07	8.70	6.31

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.45	0.87	0.00	150.00	165.00	0.45	0.24	0.00	0.24	100.00	100.00
0.34	2.14	0.00	106.00	128.00	0.34	0.60	0.00	0.60	100.00	100.00
1.96	7.88	0.31	75.00	90.50	1.96	2.21	0.18	2.39	92.52	91.95
1.39	6.60	0.30	63.00	69.00	1.39	1.85	0.17	2.02	91.46	90.80
3.50	9.70	1.57	53.00	58.00	3.50	2.72	0.90	3.62	75.04	73.12
4.99	14.14	2.95	45.00	49.00	4.99	3.96	1.70	5.66	69.99	67.69
8.58	18.44	9.8	34.04	39.52	8.58	5.17	5.64	10.81	47.80	43.79
16.73	17.83	24.16	23.72	28.88	16.73	5.00	13.91	18.91	26.42	20.77
17.71	7.99	24.8	15.47	19.59	17.71	2.24	14.28	16.52	13.55	6.92
7.70	1.40	12.36	11.34	13.40	7.70	0.39	7.12	7.51	5.22	-2.05
36.65	13.01	48.75		3.90	36.65	3.65	28.07	31.72	11.49	4.70

```
PARTICLE SIZE ANALYSIS FOR MUD TEST #14          INLET PRESSURE = 207 kPa
=====================================            SOLIDS = 3%
CUT V1S5
========
 FEED   UNDER/  OVER/   SCREEN  ARIMEAN   FEED   UNDERFLOW  OVERFLOW   CALC.      Y        Yi
         FLOW   FLOW     SIZE    SIZE    FACTOR   FACTOR     FACTOR    FEED
 (gms)  (gms)   (gms)    (um)    (um)     (%)      (%)        (%)       (%)      (%)       (%)
====================  ====================================================================
                        180.00
  0.52   2.33   0.00    150.00  165.00    0.52      0.30       0.00     0.30   100.00    100.00
  0.38   5.25   0.00    106.00  128.00    0.38      0.68       0.00     0.68   100.00    100.00
  2.12  14.99   0.70     75.00   90.50    2.12      1.94       0.50     2.43    79.62     79.22
  1.44  10.24   0.78     63.00   69.00    1.44      1.32       0.55     1.88    70.55     69.97
  3.59  11.37   3.77     53.00   58.00    3.59      1.47       2.67     4.14    35.49     34.22
  5.04  11.11   6.28     45.00   49.00    5.04      1.44       4.45     5.89    24.40     22.91
  8.55  11.83  12.76     34.04   39.52    8.55      1.53       9.04    10.57    14.47     12.78
 16.69    7.6  25.18     23.72   28.88   16.69      0.98      17.84    18.82     5.22      3.35
 17.81   3.89  23.53     15.47   19.59   17.81      0.50      16.67    17.18     2.93      1.02
  7.74   0.66  10.93     11.34   13.40    7.74      0.09       7.74     7.83     1.09     -0.86
 36.12   9.15  41.07              3.90   36.12      1.18      29.10    30.28     3.91      2.01

CUT V1S7
========
                        180.00
  0.52   1.83   0.00    150.00  165.00    0.52      0.27       0.00     0.27   100.00    100.00
  0.38   4.52   0.00    106.00  128.00    0.38      0.66       0.00     0.66   100.00    100.00
  2.12  12.70   0.67     75.00   90.50    2.12      1.85       0.46     2.30    80.12     79.39
  1.44   9.63   0.65     63.00   69.00    1.44      1.40       0.44     1.84    75.91     75.02
  3.59  10.60   3.65     53.00   58.00    3.59      1.54       2.50     4.04    38.18     35.91
  5.04  11.88   5.62     45.00   49.00    5.04      1.73       3.84     5.57    31.01     28.47
  8.55  14.33  12.86     34.04   39.52    8.55      2.08       8.79    10.88    19.16     16.18
 16.69  11.99  25.01     23.72   28.88   16.69      1.74      17.10    18.84     9.25      5.91
 17.81   5.48  23.54     15.47   19.59   17.81      0.80      16.09    16.89     4.72      1.21
  7.74   0.88  10.77     11.34   13.40    7.74      0.13       7.36     7.49     1.71     -1.91
 36.12  16.16  42.23              3.90   36.12      2.35      28.87    31.22     7.53      4.12

CUT V1S4
========
                        180.00
  0.52   1.13   0.00    150.00  165.00    0.52      0.24       0.00     0.24   100.00    100.00
  0.38   2.94   0.00    106.00  128.00    0.38      0.63       0.00     0.63   100.00    100.00
  2.12   8.89   0.62     75.00   90.50    2.12      1.91       0.39     2.30    83.10     81.55
  1.44   6.22   0.71     63.00   69.00    1.44      1.34       0.45     1.78    75.03     72.73
  3.59  10.35   3.29     53.00   58.00    3.59      2.23       2.07     4.29    51.90     47.47
  5.04  11.63   5.45     45.00   49.00    5.04      2.50       3.42     5.93    42.26     36.94
  8.55  14.16  13.71     34.04   39.52    8.55      3.05       8.61    11.66    26.16     19.36
 16.69  14.95  25.09     23.72   28.88   16.69      3.22      15.75    18.97    16.97      9.32
 17.81  10.05  23.66     15.47   19.59   17.81      2.16      14.85    17.02    12.72      4.68
  7.74   2.79  11.22     11.34   13.40    7.74      0.60       7.04     7.64     7.86     -0.62
 36.12  16.89  41.25              3.90   36.12      3.64      25.90    29.53    12.31      4.24
```

PARTICLE SIZE ANALYSIS FOR MUD TEST #15

INLET PRESSURE = 207 kPa

SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.58	2.23	0.00	150.00	165.00	0.58	0.32	0.00	0.32	100.00	100.00
0.42	4.39	0.18	106.00	128.00	0.42	0.62	0.13	0.75	82.48	82.01
2.28	9.68	1.36	75.00	90.50	2.28	1.37	1.00	2.37	57.87	56.76
1.49	5.08	1.29	63.00	69.00	1.49	0.72	0.95	1.67	43.18	41.68
3.68	5.94	4.85	53.00	58.00	3.68	0.84	3.56	4.41	19.12	16.98
5.10	5.83	7.30	45.00	49.00	5.10	0.83	5.36	6.19	13.35	11.07
8.52	7.06	14.94	34.04	39.52	8.52	1.00	10.98	11.98	8.36	5.94
16.66	5.95	25.04	23.72	28.88	16.66	0.84	18.40	19.24	4.38	1.86
17.91	2.76	22.82	15.47	19.59	17.91	0.39	16.76	17.16	2.28	-0.30
7.78	0.42	10.39	11.34	13.40	7.78	0.06	7.63	7.69	0.77	-1.84
35.58	8.29	36.83		3.90	35.58	1.18	27.06	28.23	4.16	1.63

CUT V1S7

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.58	2.27	0.00	150.00	165.00	0.58	0.29	0.00	0.29	100.00	100.00
0.42	5.58	0.00	106.00	128.00	0.42	0.72	0.00	0.72	100.00	100.00
2.28	11.26	1.36	75.00	90.50	2.28	1.46	0.97	2.42	60.10	58.11
1.49	6.36	1.28	63.00	69.00	1.49	0.82	0.91	1.73	47.48	44.86
3.68	7.51	5.08	53.00	58.00	3.68	0.97	3.61	4.58	21.20	17.27
5.10	9.03	6.75	45.00	49.00	5.10	1.17	4.80	5.96	19.57	15.57
8.52	10.99	14.74	34.04	39.52	8.52	1.42	10.48	11.90	11.94	7.56
16.66	11.42	24.16	23.72	28.88	16.66	1.48	17.17	18.65	7.92	3.34
17.91	7.61	23.35	15.47	19.59	17.91	0.98	16.60	17.58	5.60	0.90
7.78	1.62	10.18	11.34	13.40	7.78	0.21	7.24	7.44	2.81	-2.02
35.58	12.66	38.10		3.90	35.58	1.64	27.08	28.72	5.70	1.01

CUT V1S4

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.58	1.52	0.00	150.00	165.00	0.58	0.28	0.00	0.28	100.00	100.00
0.42	3.46	0.19	106.00	128.00	0.42	0.64	0.12	0.77	83.88	82.12
2.28	8.22	1.30	75.00	90.50	2.28	1.53	0.85	2.38	64.38	60.49
1.49	5.28	1.22	63.00	69.00	1.49	0.98	0.79	1.78	55.30	50.41
3.68	6.99	4.85	53.00	58.00	3.68	1.30	3.16	4.46	29.17	21.44
5.10	8.53	7.44	45.00	49.00	5.10	1.59	4.84	6.43	24.68	16.45
8.52	13.97	15.3	34.04	39.52	8.52	2.60	9.96	12.56	20.70	12.03
16.66	15.73	25.74	23.72	28.88	16.66	2.93	16.76	19.69	14.87	5.57
17.91	11.83	23.61	15.47	19.59	17.91	2.20	15.37	17.57	12.53	2.97
7.78	2.83	11.02	11.34	13.40	7.78	0.53	7.18	7.70	6.84	-3.34
35.58	21.64	34.33		3.90	35.58	4.03	22.35	26.38	15.27	6.01

PARTICLE SIZE ANALYSIS FOR MUD TEST #16 INLET PRESSURE = 207 kPa
====================================== SOLIDS = 3%

CUT V1S5
========

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.66	2.55	0.00	150.00	165.00	0.66	0.32	0.00	0.32	100.00	100.00
0.47	3.53	0.53	106.00	128.00	0.47	0.44	0.41	0.85	51.91	51.19
2.45	4.35	2.43	75.00	90.50	2.45	0.54	1.87	2.41	22.49	21.33
1.54	1.83	1.87	63.00	69.00	1.54	0.23	1.44	1.67	13.69	12.40
3.77	1.97	6.04	53.00	58.00	3.77	0.25	4.64	4.89	5.02	3.60
5.12	2.25	8.22	45.00	49.00	5.12	0.28	6.32	6.60	4.25	2.82
8.48	2.93	15.49	34.04	39.52	8.48	0.37	11.91	12.27	2.97	1.53
16.62	2.40	24.92	23.72	28.88	16.62	0.30	19.16	19.46	1.54	0.07
18.01	1.25	22.60	15.47	19.59	18.01	0.16	17.37	17.53	0.89	-0.59
7.82	0.29	9.97	11.34	13.40	7.82	0.04	7.66	7.70	0.47	-1.02
35.06	7.95	32.93		3.90	35.06	0.99	25.32	26.31	3.77	2.33

CUT V1S7
========

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.66	2.04	0.00	150.00	165.00	0.66	0.31	0.00	0.31	100.00	100.00
0.47	3.30	0.26	106.00	128.00	0.47	0.51	0.19	0.69	73.05	71.28
2.45	5.53	2.65	75.00	90.50	2.45	0.85	1.91	2.76	30.83	26.28
1.54	3.17	1.93	63.00	69.00	1.54	0.49	1.39	1.88	2[illegible].97	21.10
3.77	3.71	6.06	53.00	58.00	3.77	0.57	4.36	4.93	1[illegible].57	5.75
5.12	5.72	8.18	45.00	49.00	5.12	0.88	5.89	6.77	13.00	7.27
8.48	8.49	12.28	34.04	39.52	8.48	1.31	8.84	10.15	12.87	7.14
16.62	9.70	17.78	23.72	28.88	16.62	1.49	12.80	14.29	10.44	4.55
18.01	8.00	23.22	15.47	19.59	18.01	1.23	16.72	17.95	6.86	0.73
7.82	2.16	12.41	11.34	13.40	7.82	0.33	8.94	9.27	3.58	-2.76
35.06	13.20	40.23		3.90	35.06	2.03	28.97	31.00	6.55	0.40

CUT V1S4
========

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.66	1.70	0.00	150.00	165.00	0.66	0.29	0.00	0.29	100.00	100.00
0.47	3.28	0.61	106.00	128.00	0.47	0.56	0.40	0.97	58.08	52.40
2.45	5.88	2.88	75.00	90.50	2.45	1.00	1.91	2.92	34.47	25.59
1.54	3.22	1.81	63.00	69.00	1.54	0.55	1.20	1.75	31.43	22.14
3.77	5.42	5.46	53.00	58.00	3.77	0.93	3.62	4.55	20.37	9.58
5.12	8.21	7.96	45.00	49.00	5.12	1.40	5.28	6.68	21.00	10.29
8.48	12.11	15.96	34.04	39.52	8.48	2.07	10.59	12.66	16.35	5.02
16.62	15.92	25.00	23.72	28.88	16.62	2.72	16.58	19.30	14.10	2.46
18.01	14.21	22.72	15.47	19.59	18.01	2.43	15.07	17.50	13.88	2.21
7.82	4.74	9.95	11.34	13.40	7.82	0.81	6.60	7.41	10.93	-1.13
35.06	25.31	32.65		3.90	35.06	4.33	21.66	25.98	16.65	5.36

PARTICLE SIZE ANALYSIS FOR MUD TEST #17

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.72	1.34	0.00	150.00	165.00	0.72	0.16	0.00	0.16	100.00	100.00
0.51	1.06	1.13	106.00	128.00	0.51	0.13	0.86	1.00	13.11	10.00
2.61	1.82	3.27	75.00	90.50	2.61	0.22	2.50	2.73	8.22	4.93
1.59	0.94	2.19	63.00	69.00	1.59	0.12	1.68	1.79	6.46	3.11
3.86	1.58	6.29	53.00	58.00	3.86	0.19	4.81	5.01	3.88	0.44
5.20	2.56	9.40	45.00	49.00	5.20	0.32	7.19	7.51	4.20	0.76
8.45	4.65	16.81	34.04	39.52	8.45	0.57	12.87	13.44	4.26	0.83
16.59	5.38	25.04	23.72	28.88	16.59	0.66	19.16	19.83	3.34	-0.12
18.11	7.59	22.42	15.47	19.59	18.11	0.93	17.16	18.09	5.16	1.77
7.86	0.73	9.96	11.34	13.40	7.86	0.09	7.62	7.71	1.17	-2.38
34.50	7.52	28.49		3.90	34.50	0.93	21.81	22.73	4.07	0.63

CUT V1S7

			180.00							
0.72	1.62	0.00	150.00	165.00	0.72	0.23	0.00	0.23	100.00	100.00
0.51	1.68	1.04	106.00	128.00	0.51	0.24	0.77	1.01	23.40	19.45
2.61	2.84	3.46	75.00	90.50	2.61	0.40	2.57	2.97	13.44	8.97
1.59	1.41	2.10	63.00	69.00	1.59	0.20	1.56	1.76	11.27	6.69
3.86	2.48	7.32	53.00	58.00	3.86	0.35	5.44	5.79	6.02	1.17
5.20	3.66	9.11	45.00	49.00	5.20	0.51	6.77	7.28	7.06	2.26
8.45	6.57	17.69	34.04	39.52	8.45	0.92	13.14	14.06	6.56	1.74
16.59	8.11	26.51	23.72	28.88	16.59	1.14	19.69	20.83	5.47	0.59
18.11	6.79	23.52	15.47	19.59	18.11	0.95	17.47	18.42	5.18	0.28
7.86	1.52	10.86	11.34	13.40	7.86	0.21	8.07	8.28	2.58	-2.45
34.50	14.21	23.39		3.90	34.50	2.00	17.37	19.37	10.31	5.68

CUT V1S4

			180.00							
0.72	1.60	0.00	150.00	165.00	0.72	0.26	0.00	0.26	100.00	100.00
0.51	1.96	1.08	106.00	128.00	0.51	0.31	0.76	1.07	29.36	21.66
2.61	3.78	3.27	75.00	90.50	2.61	0.61	2.29	2.90	20.94	12.32
1.59	2.05	2.10	63.00	69.00	1.59	0.33	1.47	1.80	18.27	9.37
3.86	3.54	6.88	53.00	58.00	3.86	0.57	4.82	5.39	10.54	0.79
5.20	5.29	8.99	45.00	49.00	5.20	0.85	6.30	7.15	11.88	2.27
8.45	10.17	17.58	34.04	39.52	8.45	1.63	12.33	13.96	11.70	2.07
16.59	13.68	26.63	23.72	28.88	16.59	2.20	18.67	20.87	10.53	0.77
18.11	13.12	23.57	15.47	19.59	18.11	2.11	16.53	18.63	11.31	1.64
7.86	4.37	10.97	11.34	13.40	7.86	0.70	7.69	8.39	8.36	-1.63
34.50	17.33	23.93		3.90	34.50	2.78	16.78	19.56	14.23	4.88

PARTICLE SIZE ANALYSIS FOR MUD TEST #18

INLET PRESSURE = 207 kPa
SOLIDS = 3%

CUT V1S5

FEED (gms)	UNDER/ FLOW (gms)	OVER/ FLOW (gms)	SCREEN SIZE (um)	ARIMEAN SIZE (um)	FEED FACTOR (%)	UNDERFLOW FACTOR (%)	OVERFLOW FACTOR (%)	CALC. FEED (%)	Y (%)	Yi (%)
			180.00							
0.79	0.27	0.25	150.00	165.00	0.79	0.04	0.19	0.23	15.92	12.46
0.55	0.37	1.42	106.00	128.00	0.55	0.05	1.08	1.13	4.37	0.44
2.78	1.01	3.83	75.00	90.50	2.78	0.14	2.93	3.06	4.42	0.49
1.64	0.71	2.28	63.00	69.00	1.64	0.10	1.74	1.84	5.18	1.28
3.95	1.31	7.00	53.00	58.00	3.95	0.18	5.35	5.52	3.18	-0.81
5.25	2.24	9.45	45.00	49.00	5.25	0.30	7.22	7.52	3.99	0.04
8.42	4.48	17.37	34.04	39.52	8.42	0.60	13.27	13.87	4.33	0.39
16.55	5.67	25.87	23.72	28.88	16.55	0.76	19.76	20.52	3.70	-0.26
18.21	5.82	23.07	15.47	19.59	18.21	0.78	17.63	18.40	4.24	0.30
7.91	2.10	10.29	11.34	13.40	7.91	0.28	7.86	8.14	3.45	-0.52
33.95	9.62	24.17		3.90	33.95	1.29	18.47	19.75	6.52	2.68

CUT V1S7

			180.00							
0.79	0.54	0.25	150.00	165.00	0.79	0.07	0.18	0.25	27.99	22.17
0.55	0.89	1.53	106.00	128.00	0.55	0.12	1.11	1.23	9.48	2.16
2.78	2.22	3.90	75.00	90.50	2.78	0.29	2.83	3.12	9.29	1.96
1.64	1.36	2.27	63.00	69.00	1.64	0.18	1.65	1.82	9.73	2.43
3.95	2.86	7.25	53.00	58.00	3.95	0.37	5.26	5.63	6.63	-0.92
5.25	4.67	9.76	45.00	49.00	5.25	0.61	7.08	7.69	7.93	0.48
8.42	9.02	18.54	34.04	39.52	8.42	1.18	13.45	14.63	8.05	0.62
16.55	12.24	26.54	23.72	28.88	16.55	1.60	19.25	20.85	7.66	0.20
18.21	12.23	23.33	15.47	19.59	18.21	1.60	16.92	18.52	8.62	1.23
7.91	4.31	10.70	11.34	13.40	7.91	0.56	7.76	8.32	6.76	-0.78
33.95	21.05	20.93		3.90	33.95	2.75	15.18	17.93	15.33	8.48

CUT V1S4

			180.00							
0.79	0.69	0.24	150.00	165.00	0.79	0.12	0.16	0.28	42.82	33.07
0.55	1.21	1.29	106.00	128.00	0.55	0.21	0.87	1.08	19.64	5.92
2.78	2.90	3.83	75.00	90.50	2.78	0.51	2.58	3.09	16.48	2.22
1.64	2.32	2.18	63.00	69.00	1.64	0.41	1.47	1.88	21.71	8.34
3.95	3.67	7.14	53.00	58.00	3.95	0.64	4.82	5.46	11.81	-3.24
5.25	6.31	9.40	45.00	49.00	5.25	1.11	6.34	7.45	14.89	0.36
8.42	11.87	17.98	34.04	39.52	8.42	2.09	12.13	14.21	14.68	0.11
16.55	16.50	26.11	23.72	28.88	16.55	2.90	17.61	20.51	14.14	-0.52
18.21	15.92	23.08	15.47	19.59	18.21	2.80	15.57	18.36	15.23	0.76
7.91	5.81	10.48	11.34	13.40	7.91	1.02	7.07	8.09	12.62	-2.29
33.95	22.09	23.27		3.90	33.95	3.88	15.70	19.58	19.83	6.14

Appendix E

Observed and Calculated Performance Parameters

TABLE E-1 OBSERVED AND CALCULATED PERFORMANCE PARAMETER RESULTS FROM THE WATER-ONLY DRILLING FLUIDS

WATER-ONLY DRILLING FLUID TESTS

		OBSERVED VALUES				CALCULATED VALUES			
VORTEX & SPIGOT	Du/Do	CUT SIZE (d50c) (um)	FLOW SPLIT (S)	SHARPNESS OF SEPARATION (m)	PRESSURE DROP (kPa)	CUT SIZE (d50c) (um)	FLOW SPLIT (S)	SHARPNESS OF SEPARATION (m)	PRESSURE DROP (kPa)
WATER TEST #2:									
V1/S5	0.202	14.90	0.022	4.460	207.00	11.00	0.008	2.899	321.01
V1/S7	0.282	13.90	0.018	3.150	207.00	8.75	0.025	2.927	298.03
V1/S4	0.403	6.15	0.049	2.200	207.00	7.41	0.083	2.879	197.85
V1/S3	0.605	5.50	0.210	1.320	207.00	4.78	0.338	2.231	312.46
WATER TEST #3:									
V1/S5	0.202	18.70	0.029	4.450	207.00	12.55	0.008	2.875	316.35
V1/S7	0.282	16.20	0.036	5.360	207.00	9.81	0.025	2.838	315.94
V1/S4	0.403	6.85	0.065	2.020	207.00	7.37	0.085	2.693	336.92
V1/S3	0.605	5.80	0.210	1.570	207.00	5.53	0.344	2.250	291.65
WATER TEST #4:									
V1/S5	0.202	29.00	0.043	4.330	207.00	14.84	0.008	2.796	350.50
V1/S7	0.282	23.00	0.060	5.090	207.00	11.76	0.026	2.735	331.27
V1/S4	0.403	15.20	0.073	2.960	207.00	8.78	0.087	2.651	361.95
V1/S3	0.605	6.00	0.024	1.540	207.00	6.67	0.352	2.190	299.73
WATER TEST #10:									
V2/S5	0.279	7.20	0.022	1.460	207.00	8.49	0.019	3.087	283.23
V2/S7	0.391	6.80	0.060	1.410	207.00	6.73	0.059	2.926	261.02
V2/S4	0.558	5.30	0.204	1.540	207.00	4.93	0.203	2.402	291.99
V2/S3	0.838	4.82	0.828	1.260	207.00	3.56	0.852	1.516	270.56
WATER TEST #11:									
V2/S5	0.279	13.70	0.044	2.490	207.00	9.47	0.019	2.971	306.35
V2/S7	0.391	7.90	0.075	1.410	207.00	7.46	0.060	2.844	288.64
V2/S4	0.558	5.25	0.197	1.490	207.00	5.59	0.206	2.420	296.34
V2/S3	0.838	4.30	0.864	1.260	207.00	4.06	0.867	1.493	268.70
WATER TEST #12:									
V2/S5	0.279	20.00	0.070	3.870	207.00	11.54	0.020	2.872	300.81
V2/S7	0.391	16.50	0.088	4.820	207.00	9.06	0.062	2.800	286.43
V2/S4	0.558	5.65	0.202	1.610	207.00	6.73	0.211	2.404	304.80
V2/S3	0.838	4.60	0.789	1.200	207.00	4.89	0.888	1.545	275.98

TABLE E-2 OBSERVED AND CALCULATED PERFORMANCE PARAMETER RESULTS FROM THE BENTONITE DRILLING FLUID TESTS

BENTONITE DRILLING FLUID TESTS

		OBSERVED VALUES				CALCULATED VALUES			
VORTEX & SPIGOT	Du/Do	CUT SIZE (d50c) (um)	FLOW SPLIT (S)	SHARPNESS OF SEPARATION (m)	PRESSURE DROP (kPa)	CUT SIZE (d50c) (um)	FLOW SPLIT (S)	SHARPNESS OF SEPARATION (m)	PRESSURE DROP (kPa)
MUD TEST #1:									
V1/S5	0.202	81.00	0.025	2.660	207.00	69.08	0.025	2.765	352.42
V1/S7	0.282	78.00	0.047	2.610	207.00	88.81	0.008	2.867	346.64
V1/S4	0.403	80.00	0.110	2.120	207.00	53.74	0.084	2.701	327.84
MUD TEST #2:									
V1/S5	0.202	112.00	0.031	2.930	207.00	109.46	0.008	2.836	358.68
V1/S7	0.282	106.00	0.055	2.120	207.00	86.24	0.026	2.740	346.69
V1/S4	0.403	100.00	0.124	2.230	207.00	66.10	0.086	2.664	341.89
MUD TEST #3:									
V1/S5	0.202	99.00	0.028	2.180	207.00	111.19	0.008	2.877	324.57
V1/S7	0.282	89.00	0.049	2.210	207.00	85.58	0.026	2.767	344.24
V1/S4	0.403	85.00	0.116	1.960	207.00	67.78	0.088	2.687	298.19
MUD TEST #4:									
V1/S5	0.202	37.00	0.017	4.090	207.00	59.46	0.008	2.915	332.49
V1/S7	0.282	33.50	0.029	3.230	207.00	46.75	0.026	2.874	323.89
V1/S4	0.403	30.00	0.075	2.720	207.00	36.47	0.086	2.853	297.96
V1/S3	0.605	24.50	0.250	2.290	207.00	27.09	0.347	2.178	268.77
MUD TEST #5:									
V2/S5	0.279	27.50	0.039	2.360	207.00	44.92	0.019	2.969	336.24
V2/S7	0.391	28.00	0.091	2.530	207.00	35.22	0.061	2.757	322.68
V2/S4	0.559	23.00	0.256	2.210	207.00	27.28	0.208	2.278	290.77
V3/S5	0.399	37.50	0.144	2.750	207.00	33.52	0.050	2.790	271.91
V3/S7	0.555	29.00	0.317	2.290	207.00	25.96	0.158	2.314	260.99
MUD TEST #6:									
V1/S5	0.202	37.00	0.015	4.770	276.00	73.45	0.006	2.701	401.96
V1/S7	0.282	34.00	0.022	4.500	276.00	57.58	0.018	2.669	396.36
V1/S4	0.403	28.10	0.048	3.480	276.00	46.21	0.061	2.597	325.88
V1/S3	0.605	24.50	0.221	2.930	276.00	34.28	0.247	2.090	295.34
MUD TEST #7:									
V2/S5	0.279	26.50	0.033	3.750	276.00	55.85	0.014	2.785	376.54
V2/S7	0.391	25.00	0.074	2.970	276.00	44.71	0.044	2.642	332.88
V2/S4	0.559	22.50	0.227	3.480	276.00	34.14	0.148	2.187	317.43